Self Regulated Anti-G Ensemble

October 2000

SELF-REGULATED ANTI-G ENSEMBLE (SAGE) CONTENTS

List of Tables and Figures

Tables

Figures

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List of Contents

EXECUTIVE SUMMARY

This report presents the results of the assessment of a prototype LIBELLE liquid-filled, anti-G suit. The assessment "program" is sometimes termed Self-Regulated Anti-G Ensemble, or SAGE. Detachment 1 (Det 1) Air Force Operational Test and Evaluation Center (AFOTEC) consulted on testing strategy, monitored centrifuge and flight tests/training, and analyzed and assessed a second stage prototype (the LIBELLE II) for this report. Ground evaluations (including altitude chamber, centrifuge training, and T-38, F-15, and F-16 cockpit evaluations) were conducted 17-19 July 2000 at Brooks AFB, TX. Flight tests in the F-16B and T-38A and a simulated water landing test were conducted from 22 July to 4 Aug at the Air Force Flight Test Center (AFFTC), Edwards AFB, CA. Three flights (total 2.3 hours) in the T-38A and fifteen flights (total 13.2 hours) in the F-16B were flown. This test built on the results of a previous Test Pilot School (TPS) student project entitled HAVE LIBELLE (test of the LIBELLE I prototype, March 2000) that involved the centrifuge at Holloman AFB, NM, and 14 flights at Edwards AFB. Additional information has been provided by 311 Human Systems Wing (HSW) to assess the cost/benefits of a LIBELLE type anti-G protection system over the currently used USAF systems.

The LIBELLE II anti-G suit was designed by Life Support Systems AG™ (LSS), Zurich, Switzerland, as a full-body, self-regulating, liquid-filled, anti-G suit constructed of a Nomex/Kevlar material. Unlike the LIBELLE I suit used in the March 2000 TPS student project, the LIBELLE II suit version evaluated in this report did not require a G valve to pre-tension the suit against the wearer's skin.

The overall goal of this Battlelab initiative was to assess the state of the technology and potential benefits of the LIBELLE concept. Specific test and demonstration objectives were to:

1. Demonstrate the concept of a self-regulating, liquid-filled, anti-G suit and assess the feasibility of integration into USAF flight operations.
2. Assess the performance and safety-of-flight characteristics of the LIBELLE anti-G suit under the controlled conditions of the human centrifuge.
3. Demonstrate the effectiveness of the LIBELLE anti-G suit through in-flight utilization by aircrew.
4. Assess the military utility of the LIBELLE concept with regard to projected cost/benefit of supply, logistics, maintenance, training, safety, etc.

The basic methodology was to execute high-G flights in the LIBELLE II flight suit and to give questionnaires to the pilot subjects (of test). Pilots were not graded on ability to perform maneuvers at high-G.

Yes, increased G capability; yes, increased combat effectiveness; big tactical advantage of being able to talk.

Col. Hank Morrow

Can talk, think, and fight at 9 G for longer in LIBELLE than in Edge .

Maj. Aaron George

The LIBELLE II anti-G suit was considered *SATISFACTORY* or *HIGH SATISFACTORY* for anti-G protection and offered some additional advantages over the COMBAT EDGE and the CSU-13 B/P (both "standard" USAF G-suits); however, in its current prototype form, the suit was only rated *MARGINAL* for flight suitability. The overall conclusion of the test team was that, for most pilots, the LIBELLE II provides equal to or better G protection than COMBAT EDGE at high G, but it is not as comfortable or easy to don as existing equipment at one G, in or out of the cockpit. Some of the comfort and donning problems found with LIBELLE II at one G could probably be corrected by relatively minor suit modifications.

Under the objective of evaluation of anti-G protection, the improved anti-G protection provided by LIBELLE II did not afford a higher relaxed G tolerance than COMBAT EDGE or CSU-13B/P, nor was it more helpful against rapid G onset (although a few found it slightly more helpful). The LIBELLE II did **significantly decrease fatigue** and **improve verbal communication** at high G levels in most subjects. Improved verbal communication can enable the pilot to talk to his wingman and/or converse with his fellow crewmember. Significantly decreased fatigue can potentially translate to improved pilot performance and alertness and the ability to schedule more missions for the same pilot. Proper use of the suit involves muscular straining which is slightly different from the anti-G straining maneuver (AGSM) used in previous G suits and requires some specialized training. Most aircrew members wearing LIBELLE II could sustain high G levels for longer periods of time and perform mission tasks more effectively at high G than when wearing COMBAT EDGE.

Because of these positive results, the LIBELLE technology should be pursued through an acquisition program by the USAF. In the suitability category, aircrew members commented that the LIBELLE II suit slightly decreased mobility above the waist, inhibited motion at the waist, and particularly inhibited motion at the knees. The subjects desired a G-suit with greater ability to bend at the waist, to raise the upper leg, and to bend the knees. The operational impact of the current mobility issues is that preflight is more difficult and climbing in and out of the aircraft is more difficult.

Unlike the March testing, only two malfunctions (a rip in the leg of the suit and a zipper tear) occurred during the testing (the malfunctions were repaired by technicians before flight, so the effect of a malfunction on flight performance is unknown). However, in one case, the liquid bladder was pinched off by aggressive tightening of the aircraft lap belt, which caused the suit not to work. Although aircrew members felt the LIBELLE II suit was safe to fly for test flight purposes, some improvements would be necessary before full operational safety could be established.

Cost wise, the 311th HSW/YA predicts a large but somewhat undetermined initial cost of transition to the LIBELLE II G-suit. Unlike the COMBAT EDGE, the LIBELLE II does not require an anti-G air valve or a positive pressure breathing system just for anti-G tolerance, thus saving the USAF five million dollars per year in sustainment costs. Besides cost savings, less total equipment could translate into more efficient employment of an air expeditionary task force.

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INTRODUCTION

Background

This report presents the results of the limited evaluation of a prototype LIBELLE liquid-filled, anti-G suit. This effort was designed to meet the explicit goals and objectives of the USAF Aerospace Expeditionary Force Battlelab (AEFB), Mountain Home AFB, ID. The flight test was conducted under the authority of the Commandant, USAF TPS, Edwards AFB, CA. Det 1 AFOTEC (hereafter referred to as Det 1) did not participate in the March flight tests; however, for the July flight tests, Det 1, assisted by the AEFB, consulted in testing strategy, accomplished the assessment, analyzed the data, and wrote this final report. Det 1 did not participate in the test planning process but did develop and administer additional questions to all subjects, attended all briefings and debriefings, questioned all subjects, and observed most centrifuge runs and flight tapes.

Today's pneumatic anti-G suits (partial and/or complete body suits) only counteract the influence of positive acceleration ($+G_z$) forces on the pilot's body to a limited extent. ("$+G_z$" means pushing the pilot down toward the floor of the aircraft or into the pilot's seat along the "z" axis). The inadequately protected pilot can actually become the limiting factor (aircraft can pull the Gs, pilot cannot) during missions that require high-G turn performance.

Current anti-G suits (hereafter called "G-suits") are based on a pneumatic concept that dates back to 1935. Regulated by a valve and reacting to the acceleration force, compressed air taken directly from the aircraft engine or from a separate compressor is pumped into bladders or cuffs enclosing the lower part of the body. This pressure prevents blood from pooling in the pilots' legs, thereby maintaining blood pressure to the head.

The Advanced Tactical Anti-G Suit (ATAGS) is the latest USAF technology in "G-pants" and provides more complete coverage of the lower body and therefore better protection than CSU-13 B/P, the current operational USAF G-suit for high performance fighter aircraft.

The USAF COMBAT EDGE system utilizes an anti-G counter-pressure vest with positive pressure breathing in addition to the CSU-13B/P lower body G-suit. This anti-G ensemble relies upon air bladders that partially cover the body surface to squeeze the pilot's body. Since a moisture-impermeable membrane covers large sections of the body, the current suits prevent evaporative cooling as the pilot sweats, thereby increasing thermal stress on the body. Additionally, some USAF aircraft (e.g., the T-37) routinely pull Gs but do not have a G-valve for a pneumatic G-suit; therefore, before the LIBELLE, use of a G-suit was impos-

sible in these aircraft. Overall, the current generation of USAF anti-G equipment offers opportunity for improvement.

Researchers at LSS AG™ (Zurich, Switzerland) have developed a prototype LIBELLE G-suit purported to increase pilot effectiveness under high-G. The LIBELLE II is based on the use of a hydrostatic, compensating column that tightens the garment over all covered portions of the body (excluding only the head, hands, and feet) under all positive acceleration situations. The LIBELLE does not involve any moving parts (other than zippers), does not require any aircraft-mounted equipment, and regulates suit pressure automatically and simultaneously as G forces are applied to the aircraft. Such a system could also offer potential savings in maintenance and logistics due to simplicity and universality of use. The 311 HSW estimates that after the initial acquisition cost of the LIBELLE is paid, the system would save about five million dollars per year in recurrent (sustainment) costs due to non-upkeep of positive pressure breathing systems associated with the G-suit.

Program Chronology

Under the USAF TPS's HAVE LIBELLE flight test program, ground evaluations (including altitude chamber, centrifuge training, and T-38 cockpit evaluations) were conducted 20-24 March 2000, at Holloman AFB, NM, on a prototype suit entitled the LIBELLE I. F-16 cockpit evaluations and all flight tests were conducted 28 March to 06 April 2000, at the AFFTC, Edwards AFB, CA. Seven flights in the T-38A and seven flights in the F-16B were flown.[1] Later, under the LIBELLE II test (22 July to 8 August 2000), 18 flights were flown to assess the improved suit at Edwards AFB. Prior to this flight test, a week-long orientation and subject training was accomplished at the Air Force Research Lab (AFRL) centrifuge at Brooks AFB, TX. The test included fit and form and cockpit interference evaluations in F-15, T-38, and F-16 cockpit mockups at Brooks AFB. It also included parachute training at Brooks AFB and a swimming pool (ejection over water) assessment at Edwards AFB.

The second flight test built on the results of the first test (schedule in Table 1). For example, the first test demonstrated no problems due to a transition from negative to positive Gs and demonstrated no increase in relaxed G tolerance. These "test points" were therefore not accomplished during the second flight test. All of the aircraft had a second "safety" pilot equipped with a control G-suit (COMBAT EDGE and/or CSU-13B/P).

[1] Air Force Materiel Command USAF. *Limited evaluation of the LIBELLE liquid-filled, anti-G suit concept (PROJECT HAVE LIBELLE).* AFFTC-00-03, June 2000.

Table 1. Flight Schedule: This schedule permitted close-in-time comparisons of types of G-suits.

	Aircraft	Pilots
Thursday, 20 July	T-38	Lt. Col. Sizoo (first person is always in LIBELLE II)/Maj. Moss
Friday, 21 July	F-16	Maj. Prosser/Maj. Tanner
Monday, 24 July	F-16	Col. Morrow/Maj. George
Tuesday, 25 July	F-16	Col. Morrow/Maj. Prosser
	F-16	Col. Demitry/Maj. George
	F-16	Maj. Ladet in back seat/Maj. George
Wednesday, 26 July	F-16	Col. Demitry/Maj. George
	F-16	Maj. Ledet in back seat/Maj. Stucky
	F-16	Col. Munson in back seat/Maj. George
	F-16	Col. Allnutt in back seat/ Maj. Stucky
Thursday, 27 July	F-16	Col. Munson in back seat/Maj. George
	T-38	Col. Allnutt in back seast/Lt. Col. Sizoo
	F-16	Col. Demitry/Maj. George
Friday, 28 July	F-16	Maj. George/Maj. Thurling
	T-38	Col. Munson in back seat/Capt. Braden
Monday, 31 July	F-16	Maj. Prosser/Maj. Thurling
Tuesday, 1 August	F-16	Lt. Col. Sizoo/Maj. Prosser
Wednesday, 2 August	F-16	Maj. Prosser/Maj. Thurling
	F-16	Lt. Col. Sizoo/Capt. Ford
Thursday, 3 August	F-16	Lt. Col. Sizoo/Maj. Prosser
Friday, 4 August	F-16	Maj. Prosser/Lt. Col. Sizoo

Test Item Description

The LIBELLE II G-suit was designed by LSS AG™, Zurich, Switzerland, as a full-body, self-regulating, liquid-filled, G-suit. Earlier prototype suits of various configurations were evaluated by the Swiss and Germans in the centrifuge and in flight aboard the PC-7, PC-9, PC-12, Learjet, Tiger F-5E, and Mirage III. Access to their results was limited due to the proprietary nature of the suit. The prototype version of the LIBELLE suit evaluated in the March tests was not fully self-regulating since it used aircraft bleed-air and G-valve to pre-tension the suit against the wearer's skin. The July/August 2000 test employed an improved suit (LIBELLE II), which LSS designed to be totally self-regulating without any connection required to a G-valve or need for a positive pressure breathing regulator. Mobility in the legs and waist was improved by some structural changes in the suit. Testing of these suit iterations represented the first step toward USAF evaluations of the LIBELLE technology.

The LIBELLE II suit is composed of a Nomex/Kevlar outer shell with a cotton undergarment. The suit is equipped with six fluid-filled tubes running from shoulder to toe and along both arms. The tubes swell and tighten the suit under the increased hydrostatic pressure created by the $+G_z$ forces, tightening the fabric around the wearer. This tightening creates a G-compensating pressure against the skin. The suit does not significantly increase in size under G-loading, unlike current pneumatically-pressurized suits; therefore, the suit offers the possibility of using garments *over the top of* the suit, such as an anti-exposure garment. Unlike previous hydrostatic suits and most pneumatic suits, the LIBELLE II suit fabric will "breathe" because the fluid-filled tubes covering the wearer's body are limited to a small surface area instead of large bladders that covered the majority of the body in previous suits. The LIBELLE is also unique in that it was worn *in lieu* of a flight suit, compared to most conventional suits that are worn *over* the flight suit.

As a prototype, the suit lacks many of the features required of an operational ensemble, such as pockets, collar, penholders, and, perhaps, more manageable size adjustments. Also as a prototype, the suit is custom-fit for each wearer. Approximately eight suits were made for the LIBELLE II test team. Refer to Appendix B for a more detailed test item description.

This report uses the term "operational anti-G suit" in reference to the CSU-13B/P and/or COMBAT EDGE, currently used operationally by the USAF.

TEST OBJECTIVES

The overall test objective was to evaluate the utility of the LIBELLE II G-suit. The following were two specific test objectives:

- **Test Objective 1:** Anti-G protection

  Determine and compare protection against $+G_z$ provided by LIBELLE II and COMBAT EDGE G-suits.

- **Test Objective 2:** Flight Suitability

  Assess flight suitability of the LIBELLE II G-suit for T-38A and F-16B operations. Suitability is the degree to which a system can be placed satisfactorily into field use with consideration given to availability, compatibility, transportability, interoperability, reliability, wartime usage rates, maintainability, safety, human factors, man-power supportability, logistics supportability, natural environmental effects and impacts, documentation and training requirements (from the Defense Acquisition Deskbook)

The following are the LIBELLE II test objectives and associated measures of performance (MOPs) or subobjectives:

Test Objective 1—Anti-G Protection

Direct Comparison with COMBAT EDGE and CSU-13B/P

- Anti-G benefit
- Withstanding sustained high-G
- Mission accomplishment during high-G
- Sustained high-G
- Rapid G onset
- Ease of verbal communication

Indirect comparison with COMBAT EDGE and CSU-13 B/P

- Ability to accomplish mission in the sustained high-G environment
- Gray out or tunnel vision
- Fatigue tolerance at high-G
- Ability to perform the anti-G straining maneuver
- Ability to accomplish mission in high-G environment
- Rapid G onset rates
- Fatigue and workload

Test Objective 2—Suitability

All indirect comparisons with COMBAT EDGE

- Ease of donning
- Ease of doffing
- Flex and extend lower body
- Aircraft preflight
- Climbing into cockpit
- Reach cockpit controls
- Life support equipment
- Ejection posture
- Ability to “check six”
- Overall mobility
- Interference with aircraft controls
- Verbal communication at max G
- Overall comfort at 1 G
- Overall comfort at sustained high-G
- Sweating or Heat stress at high-G
- G estimation
- Safety

General

This series of tests was constructed to provide an initial evaluation of a prototype LIBELLE II G-suit to determine if the concept is worthy of further USAF consideration. From 22 July to 4 August 2000, 18 flights were flown at Edwards AFB to assess the suit. Previously, a week-long orientation and training of subjects was accomplished at the human centrifuge at Brooks AFB.

For the LIBELLE II assessment, ground evaluations (including altitude chamber, centrifuge training, T-38, F-15, and F-16 cockpit evaluations) were conducted 17-19 July 2000 at Brooks AFB, TX. Flight tests in the F-16 and T-38 and a swimming pool simulation of a water-landing test were conducted 22 July to 4 August at the AFFTC. Three flights in the T-38A and fifteen flights in the F-16B were flown. This test built on the test results of the previous (March 2000) HAVE LIBELLE TPS student project that involved the centrifuge at Holloman AFB, NM, and 14 flights. F-16B cockpit evaluations and all flight testing were conducted 28 March to 6 April 2000 at the AFFTC, Edwards AFB, CA. Seven flights in the T-38A and seven flights in the F-16B were flown. Questionnaires providing quantitative and qualitative assessments of the test article were completed after each centrifuge run and flight test sortie. Appendix C contains an example of the questionnaire.

Subjects of this test are referred to as “pilots” even though some of them were flight surgeons and were not necessarily USAF rated pilots. It is realized that some crewmembers in high-G aircraft may be navigators or other types of weapon systems operators and not exclusively pilots.

Specific Methods and Conditions

In the March 2000 HAVE LIBELLE test, the centrifuge runs were conducted in such a manner that permitted them to be part of the assessment. Due to time constraints in the second July/August 2000 LIBELLE II test, the centrifuge profiles were designed to accomplish training for the flight test. Additional centrifuge runs for data collection could not be accomplished with the time and exposure constraints imposed by the existing AFRL Human Use protocol. A short summary of the March centrifuge tests follows:

Four aircrew members received centrifuge training followed by testing at Holloman AFB from 21-24 March 2000. The G suits were connected to the centrifuge pressurization system (which is functionally similar to the aircraft bleed-air system) during all profiles, and a device was applied to the G-valve to apply a pre-tensioning pressure to the suit at 1 $+G_z$. This pre-tensioning pressure was recorded and adjusted before and after each centrifuge run. An F-16 representative 30-degree reclined seat and side

stick were used for all profiles. Centrifuge training was conducted in accordance with Air Force Instruction (AFI) 11-404. Except for the orientation runs, each centrifuge training run consisted of the F-16 qualification training profiles plus a G-estimation task.

March tests: Centrifuge training consisted of four days of training/testing. During Day 1 and part of Day 2, each aircrew member wore the LIBELLE suit on five orientation rides in the centrifuge. The purpose of the first runs was to train and become familiar with the suit and to gather qualitative comments regarding LIBELLE. The Day 3 and 4 runs were a mix of LIBELLE and COMBAT EDGE runs. The purpose of these runs was to directly compare the anti-G protection provided by each suit. At the conclusion of the centrifuge training runs, two aircrew members performed additional high-G runs to examine rapid onset and anti-G protection at sustained high-G conditions.

The July 2000 centrifuge tests were deemed "training" (as opposed to "testing") and did not permit an assessment of the LIBELLE II suits. This centrifuge training involved a steep learning curve. One subject, Maj. Arron George (who also participated in the HAVE LIBELLE test) quickly optimized his AGSM and "flew" back to back LIBELLE II and COMBAT EDGE runs. Maj. George soon reported that his LIBELLE II runs were almost a lark, which contrasted strongly with his always extremely fatiguing and sometimes painful COMBAT EDGE runs.

A ground evaluation of the LIBELLE II was conducted at Brooks AFB, TX. Four aircrew members evaluated LIBELLE II for hanging harness and ground egress from T-38, F-15, and F-16 cockpit mock-ups. A long-duration wear test, per se, was not accomplished; however, some subjects left their suits on after centrifuge runs and walked around outside in the more than 100 degree Texas summer heat in order to assess suitability in heat. During all evaluations, the LIBELLE II was filled with liquid. One aircrew member evaluated LIBELLE II in the altitude chamber. The chamber profile consisted of a slow decompression to the maximum planned cabin altitude of 10,000 ft pressure altitude (PA) and a rapid decompression simulating the worst-case pressure differential from cabin altitude to the maximum planned flight altitude (25,000 ft PA). The LIBELLE II suit was apparently not harmed by the decompression, nor did the subjects notice any adverse effects.

It was discovered during the centrifuge training that the optimal AGSM is a bit different for the LIBELLE II than that used for previous suits. In the LIBELLE II (and in previous G-suits), the pilot strains or tenses his lower body; however, in previous G-suits, the pilot often pushed his stomach out against a "hard" G-suit (abdominal bladder that bulges inward when inflated). The LIBELLE II is not hard and does not bulge inward; therefore, the pilot must learn to tuck or crunch his stomach inward. The pilots also tighten muscles of the upper body and perform a "valsalva" or respiratory strain against a partially-closed glottis.

Most described this respiratory maneuver as necessary to "get ahead of it" but not necessary once they were "on top of the Gs."

In fact, some pilots mentioned that they could relax (sometimes totally) at high-G once they were "on top of it." Further, the techniques were passed from pilot to pilot and evolved over the week in the centrifuge. The respiratory straining portion of the standard AGSM is typically maintained throughout high-G exposures when using the standard G-suit or COMBAT EDGE equipment. Because G tolerance is partly a function of straining technique employed, and this technique was different than the traditional AGSM that the pilots are accustomed to, the available centrifuge time during the week was devoted to *training for flight test*. Flight testing was conducted from 22 July to 8 August for the LIBELLE II. The flight test profile is described in Reference A.

In the July/August flight testing, the LIBELLE II G-suit was evaluated during operationally-representative air-to-air and air-to-ground maneuvers; however, the emphasis on each test flight was on "hard," high-G, steep turns. Each sortie included at least one sustained maximum-G turn for up to 720 degrees. On both series of tests, each of the three T-38A flights were approximately 0.9 hours in duration, and each of the F-16B flights were approximately 1.0 hours in duration. A negative-to-positive G maneuver performed in the March tests caused no problems for the subject pilots and was dropped from the July/August flight tests. During all flight test sorties, one aircrew member in each aircraft wore LIBELLE and a safety pilot in the other cockpit wore USAF operational G protection equipment. In the T-38, the operational G-suit worn by the safety pilot was the CSU-13B/P; in the F-16, the ensemble worn was COMBAT EDGE with the CSU-13 B/P. A summary of the flight test questionnaire results appears in the results section.

Test Limitations and Caveats

Measurement Difficulties

G-suits or anti-G physical straining maneuvers are often summarily evaluated as providing "X [a number] more Gs of protection" than some baseline. It is tempting to directly ask subjects about *extra* G protection or a delta between the LIBELLE suit and the COMBAT EDGE; however, it is difficult to directly compare the LIBELLE and the COMBAT EDGE in terms of delta G (improved G) protection for a number of reasons. Many of the pilots are "certified" as capable of sustaining nine

Gs. Furthermore, the aircraft used (and virtually all aircraft) cannot sustain more than nine Gs, so any new G-suit cannot, *by definition*, directly demonstrate greater anti-G protection than the COMBAT EDGE; however, most of the subjects reported in conversations with each other and with Det 1 testers that the LIBELLE II provided about a half G or a full G more protection than the COMBAT EDGE. More detailed questioning of the subjects revealed that an "extra G of protection," in this context, means that for a given amount of AGSM, a constant amount of G-induced problems, such as light loss, would probably ensue using the experimental suit, but at one G more than the "control" suit. Of course, this comparison cannot be directly made and is strongly subjective.

Further clouding this "extra G" issue and confounding any direct side-by-side comparison are the following experiment-related issues:

1. Some subjects said that what they meant by extra G protection is less fatigue and greater ability to communicate at a given G level; however, these stated advantages are later offered in this report as independent of or orthogonal to extra G protection (in Obj 2, Suitability). The point is that it is difficult to specifically define extra G protection independently of other advantages.

2. The anti-G straining maneuver is not just a matter of degree of use, but instead a change of *qualitative* technique in this experiment. So it is impossible to say that, for the very same amount of strain, the delta Gs (between types of G-suit) sustained is X [a number] because the type of strain is slightly different and dependent on the type of G-suit.

3. The T-38 test aircraft is structurally limited to about seven Gs. A pilot in the G-suit could probably sustain more. This aircraft can employ the LIBELLE II, but not the COMBAT EDGE (instead, the CSU 13 B/P was used as the control suit).

4. It is not possible in the cockpit to directly measure pilot strain.

5. G tolerance seems to be a function of fatigue, G onset rate, the G level that started the maneuver, and heart rate at the beginning of the maneuver. The bottom line is that direct comparisons are, by nature of the experiment, somewhat confounded and clouded by experimental noise.

Caveats on the Utility/Suitability Tradeoff

A number of subjects were directly approached and asked if they would prefer the LIBELLE II flight suit over the present COMBAT EDGE ensemble if they were to go to war tomorrow. The idea was to obtain a layer of pilot judgement concerning whether better G tolerance

counter balances other problems or negatives in the suitability category. This prototype was more comfortable and suitable than the HAVE LIBELLE test article worn on March 2000, since the company has established a track record of continuous improvement, we expect further development to continue; however, it was discovered that subjects could not answer the question directly, primarily because the "suit" is still a technology and not fully developed at this point. For example, the suit does not have pencil pockets. Many pilots remarked that the lack of pockets was a problem, but pencil pockets could be easily added.

Other Limitations of the Assessment

- F-15 cockpits were used for fit and function testing; however, the F-15 and its upright (not reclined) seat were not tested. (The T-38 and its unreclined seat were tested, but not beyond seven Gs).
- Rear-seat F-15s and many other cockpits (e.g., F-117) were not tested for fit and function.
- Experts were *asked* if they foresaw problems with many aspects of G-suit wear such as ejection; however, ejection and many other aspects were certainly *not tested*.
- The hypothesis that if pilots report they are less tired, then they would perform better was not specifically tested. Pilots were not "graded" on any maneuvers.
- No extended flights occurred.
- All reliability and maintainability data is anecdotal.
- Experts from the developer's company fitted the LIBELLE II suit to individuals. Effects of ill fit, even that due to weight gain or loss over time, were not tested.

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General Assessment Methodology and Choice of Subjects

Appendix D details statistical comparisons and Reference A talks to classification of comparers and gives qualifications. In short summary, the "master comparers" have recently and frequently flown the COMBAT EDGE at high-G (besides flying the LIBELLE II), and are, therefore, particularly well qualified to compare G-suits.

Figure 1. The Assessment Team: The assessment team offered a diverse background of experience.

There are essentially two categories of subjects that are included in the database.

As stated, the master comparers are all senior fighter pilots (three are also experimental test pilots) who have recently and frequently flown the COMBAT EDGE (Figure 1). In fact, they flew the COMBAT EDGE at high-G recently and filled out a questionnaire for this test; therefore, the master comparers are particularly well qualified to evaluate the LIBELLE II and to compare it to the COMBAT EDGE.

The non-master comparers have a slight handicap since they have not flown the COMBAT EDGE at high-G recently and frequently, and are not necessarily pilots. In fact, two non-masters flew the CSU-13 B/P during this test and have not flown the COMBAT EDGE recently; thus, their questionnaire data are of slightly questionable validity. In every case, though, each non-master fully participated in the test, bringing with them a special brand of expertise. For example, three flight surgeons had among them considerable experimentation and training in centrifuge experience, program management in G-suit program experience, and expertise concerning the physiology of the G-suit (how the suit works).

In summary, only the master comparers' results are shown in the graphs. Additionally, only the master comparers' last flight was counted in order to minimize "learning" effects, so each data point could be considered as valid as possible; however, for completeness, comments are made concerning the effect of enlarging the database. Also, comments of the non-masters were included in the explanatory comments.

Answers to the first five questions are analyzed here since they point-blank ask the subjects to compare G-suits; therefore, the results beg for a certain type of presentation of results. The later questions and results are handled differently. The results are posted by measure of effectiveness (MOE) (or subobjective) and summarized by category.

Direct Comparison of LIBELLE II with COMBAT EDGE

Anti-G Benefit

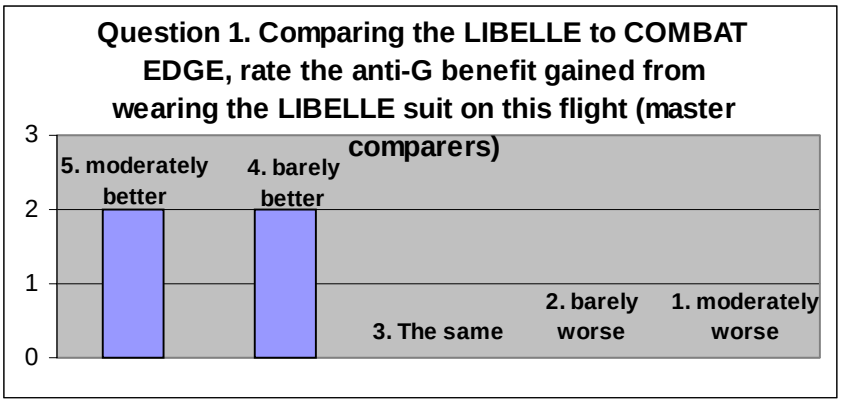

Figure 2. All subjects preferred the LIBELLE for anti-G benefit.

One can summarize by stating that all master comparers preferred the LIBELLE II to the COMBAT EDGE in terms of anti-G benefit. One score was backed off to a "4" when the subject called it a "4.5," which was not one of the options. Two said "moderately better," and two said "barely better."

Considering and including earlier flights of the very same subjects had no appreciable effect on results. This fact implies that for this particular question and these particular subjects, learning effects were minimal.

Explanatory comments were:

- "Much less physically demanding."
- At debriefing, a subject reported that he was "super fresh," as though he did just enough physical exercise to be thoroughly warmed up.
- At another time, the same subject said that he was "a different kind of tired" after a flight with the LIBELLE II, as a person would be just after a wind sprint. This differs from the muscular fatigue he felt in the COMBAT EDGE.

Adding other subjects to the master comparers—not more flights of the same people—adds ambivalence (see below).

On this same question, two other subjects, Colonel (Dr.) Robert Munsen and Colonel (Dr.) Allnut, both reported that the LIBELLE II was "barely worse" than the COMBAT EDGE in their last F-16 ride; however, they both reported "moderately better" results in a T-38A flight the following day. Should one accept the F-16 ride (very high-G) or instead the last ride as *the* representative sample? It appeared (and the two subjects confirmed) that the change in results were due to a steep

learning curve at the very end of the flight test, but this hypothesis could not be checked with another F-16 flight; therefore, it was decided to eliminate both subjects from the entire database except for anecdotal comments.

The results were essentially the same as the March 2000 HAVE LIBELLE results.

Withstanding Sustained High-G

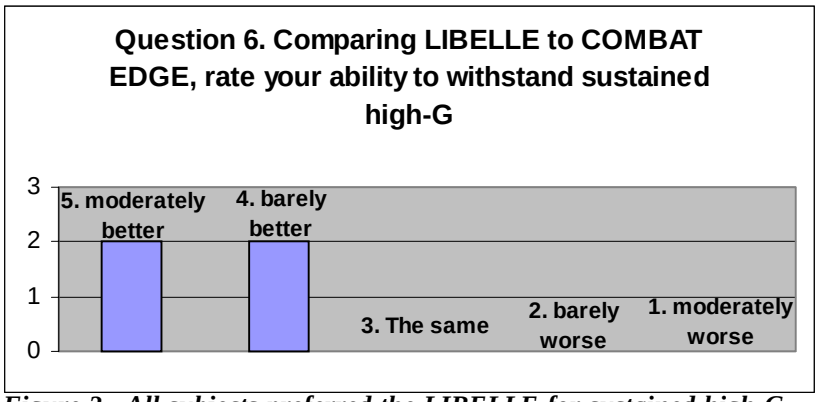

Figure 3. All subjects preferred the LIBELLE for sustained high-G.

Results were the same positive results as the last (and similar) question.

Considering and including earlier flights of the same subjects showed that these posted scores were much better than scores from earlier flights. Again, this is an indication of learning. Including the two other subjects (comparers but not qualified to be masters) did not have an appreciable effect on results, but would have made them even more positive for the LIBELLE II. One could conclude, therefore, consistency among all of the subjects for this particular question.

These results were essentially the same as the HAVE LIBELLE results.

Amplifying comments were:

- "Easier strain means that I can do more work at high-G. I was able to fight and talk there."
- "[I was] able to relax (fully) after about 5 seconds at 9 G's initial strain. [However] I felt as if I had to raise my blood pressure first."

Workload During High-G

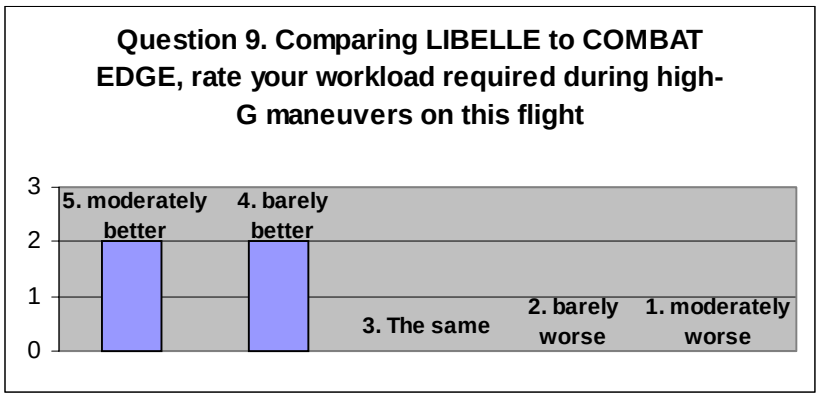

Figure 4. All subjects preferred LIBELLE for lowered workload.

Results were the same positive results as the last question.

Considering and including earlier flights of the same subjects showed that these scores were better than earlier flights (again, learning was demonstrated). Including the two other subjects (comparers but not qualified to be masters) did not have an appreciable effect on results. These results were almost exactly the same as the HAVE LIBELLE March 2000 results.

Comments were:

- "Workload is about 60 percent less physically."

Results were very positive, as shown.

Mission Accomplishment at Sustained High-G

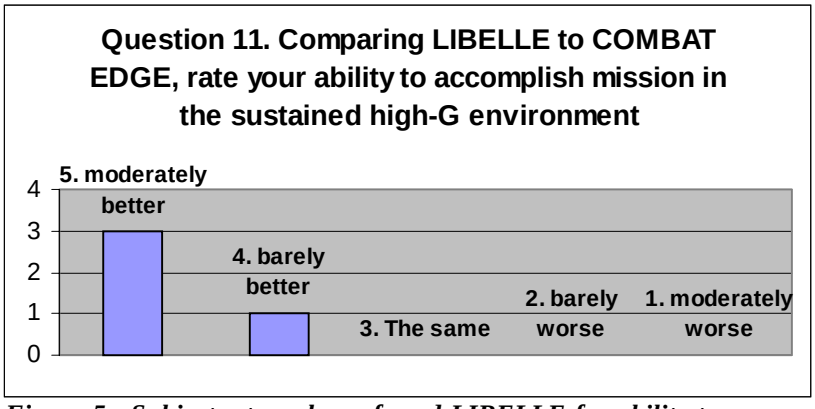

Figure 5. Subjects strongly preferred LIBELLE for ability to accomplish mission in sustained high-G.

Considering and including earlier flights of the same subjects showed that these scores were much better than earlier flights. Again, this shows learning. Including the two other subjects (comparers but not qualified to be masters) did not have an appreciable effect on results. Results were a little more positive than HAVE LIBELLE results.

Comments were:

- "Ability to relax and talk at nine Gs was evident."

Rapid G Onset

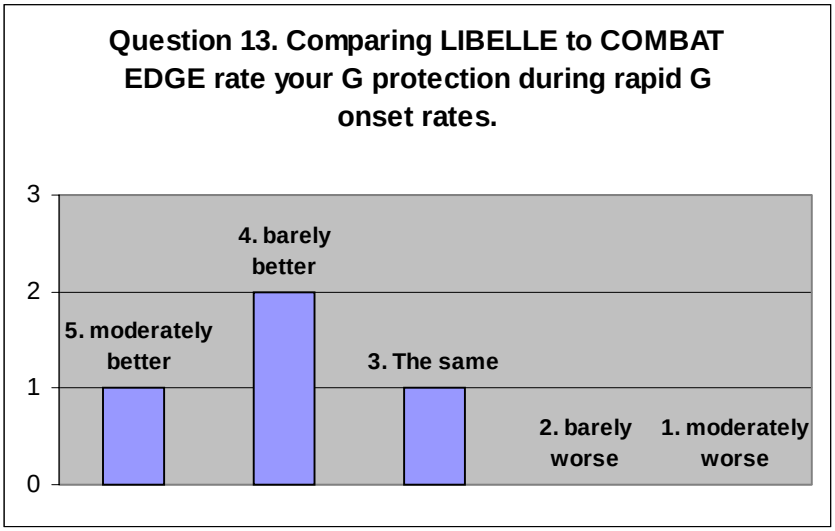

Figure 6. Subjects preferred LIBELLE for rapid G onset rates, but only slightly.

Results were very positive as shown.

Considering and including earlier flights of the same subjects showed that earlier scores indicated that both G-suits are the same. Including the two other subjects (comparers but not qualified to be masters) did not have an appreciable effect on results. The results were a little more positive than the same as the March 2000 HAVE LIBELLE results.

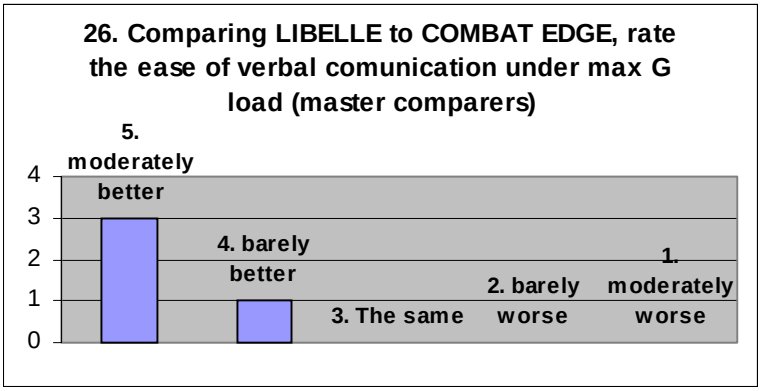

Figure 7. Subjects strongly preferred LIBELLE for better verbal communication.

Results were very positive, as shown.

Considering and including earlier flights of the same subjects showed that these scores were about the same as earlier flights. Including the two other subjects (comparers not qualified to be masters) did not have an appreciable effect on results.

Results were about the same as HAVE LIBELLE results.

Summary of Anti-G Comparison Direct Comparison Averages (Medians)

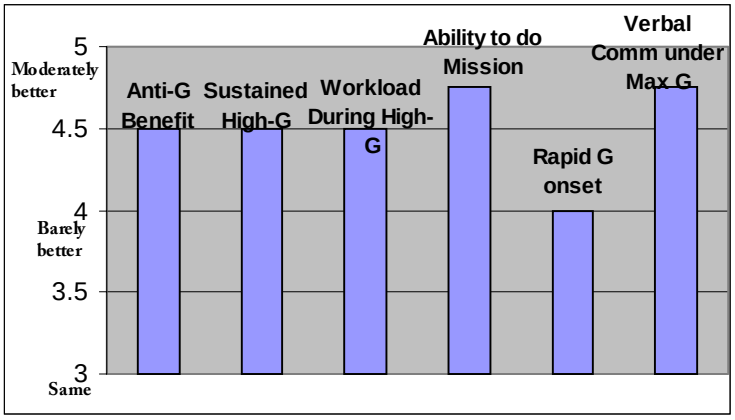

Figure 8. Subjects preferred LIBELLE in all categories.

To summarize the above, the LIBELLE II is superior in all stated aspects of high-G flight, except that it is not clearly better in rapid G onset.

Indirect comparison with COMBAT EDGE

Other questions asked the same subjects to evaluate the LIBELLE II *absolutely* rather than relative to the COMBAT EDGE (again see Reference A statistics for details). Since the subjects were asked the same questions about the COMBAT EDGE, it is possible to put both results on the same graphs in order to make a comparison (even though the questionnaire did not ask for a comparison).

Gray Out or Tunnel Vision

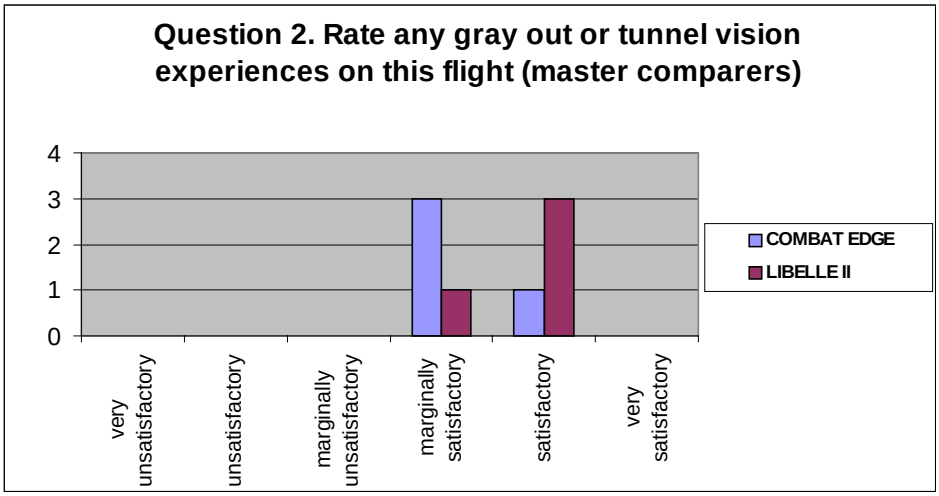

Figure 9. Subjects preferred the LIBELLE and rated it a low satisfactory for gray out.

Just looking at the red (LIBELLE II) bars indicates that on an absolute scale, the LIBELLE II was rated at least satisfactory by all of the master comparers. The fact that the LIBELLE II scores are generally to the right of the COMBAT EDGE scores indicates that the LIBELLE II was generally rated above the COMBAT EDGE in this question. In fact, two of the master comparers rated the LIBELLE II one category better than the COMBAT EDGE. Two rated the two G-suits in the same category.

Considering and including earlier flights of the master comparers would have caused one “marginally unsatisfactory” grade. Including the other four subjects (comparers but not qualified to be “masters”) would have increased the variance with a “marginally unsatisfactory” and a “very satisfactory.”

Results were much more positive than HAVE LIBELLE results.

Amplifying comments were:

- "Did not have the same control over my strain that I had in centrifuge, and I had more difficulty controlling gray out."

(This comment was from an earlier flight).

This question was from a relaxed G tolerance part of the questionnaire, but it is not clear that all subjects interpreted it that way.

Fatigue tolerance at High-G

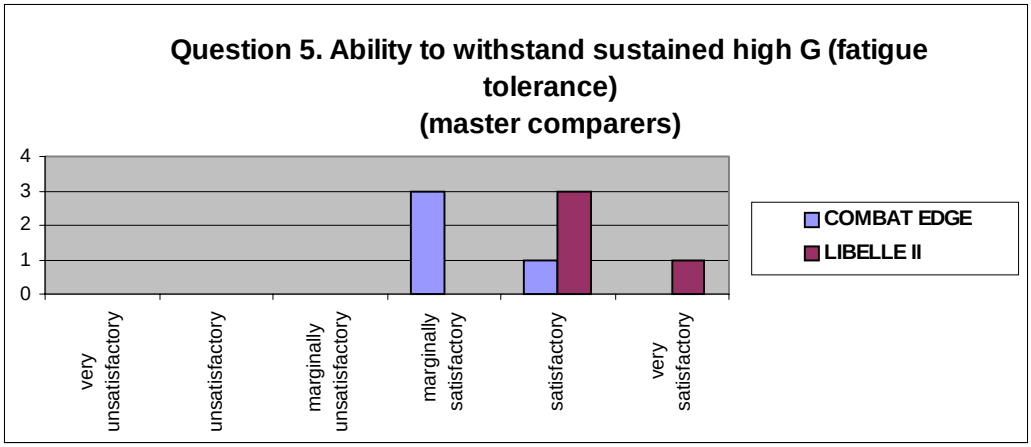

Figure 10. Subjects preferred the LIBELLE and rated it a high satisfactory on fatigue tolerance.

Just looking at the red (LIBELLE II) bars reveals that on an absolute scale, the LIBELLE II was rated at least satisfactory by all of the master comparers. The fact that the LIBELLE II scores are generally to the right of the COMBAT EDGE scores indicates that the LIBELLE II was generally rated above the COMBAT EDGE in this question. In fact, three of the four master comparers rated the LIBELLE II at least one category better than the COMBAT EDGE (one rated it two categories better). One rated the two G-suits in the same category.

Considering and including earlier flights of the master comparers would have lowered the scores. Including the other four subjects (comparers but not qualified to be "masters") would have lowered average scores and increased the variance with a "unsatisfactory" and three "satisfactories."

Results are slightly less positive than the HAVE LIBELLE results

Amplifying comments were:

- "This is very apparent due to the lower workload when using LIBELLE suit." [apparently "this" means great tolerance]

Ability to Perform the Anti-G Straining Maneuver

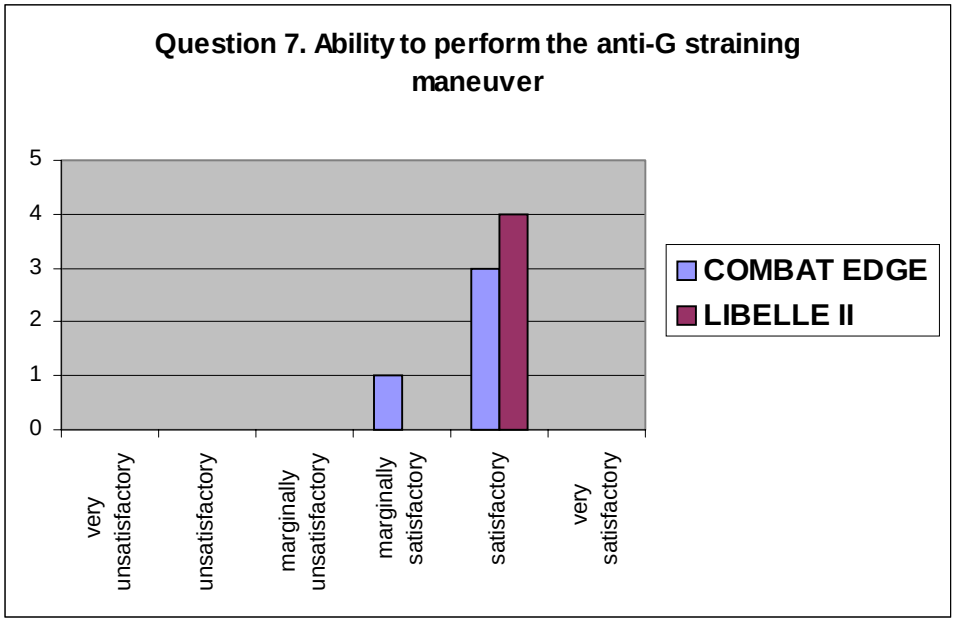

Figure 11. Subjects preferred the LIBELLE and rated it satisfactory in AGSM.

As covered later in this section, the AGSM was somewhat different for the LIBELLE II than for the COMBAT EDGE.

Looking at the LIBELLE II bars reveals that on an absolute scale, the LIBELLE II was rated at exactly satisfactory by all of the master comparers. The fact that the LIBELLE II scores are slightly to the right of the COMBAT EDGE scores indicates that the LIBELLE II was rated above the COMBAT EDGE in this question. In fact, one master comparer rated the LIBELLE II one category better than the COMBAT EDGE.

Considering and including earlier flights of the master comparers would have lowered the average grade. Including the other four subjects (comparers but not qualified to be "masters") would have decreased the average score slightly with one "marginally satisfactory."

Amplifying comments were:

- "Still reverting to L-1 [the older AGSM that is supposed to be used with the COMBAT EDGE] at times."

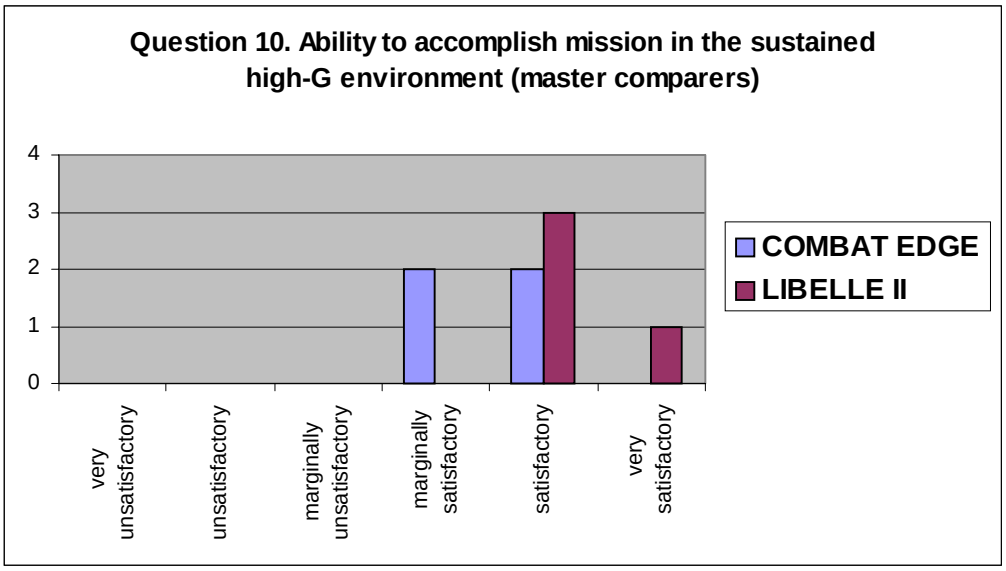

Figure 12. Subjects preferred the LIBELLE and rated it high satisfactory in ability to accomplish mission.

Looking at the red (LIBELLE II) bars reveals that on an absolute scale, the LIBELLE II was rated at least satisfactory by all of the master comparers. The fact that the LIBELLE II scores are generally to the right of the COMBAT EDGE scores indicates that the LIBELLE II was generally rated above the COMBAT EDGE in this question. In fact, three of the four master comparers rated the LIBELLE II one category better than the COMBAT EDGE. One rated the two G-suits in the same category.

Considering and including earlier flights of the master comparers would have lowered the grades. Including the other four subjects (comparers but not qualified to be "masters") would have slightly lowered average scores and increased the variance with an "unsatisfactory" and two "satisfactories."

Results are slightly better than the HAVE LIBELLE results on an absolute scale, but the HAVE LIBELLE results were not as good concerning the COMBAT EDGE.

Amplifying comments were:

- "Much better due to workload."
- "Lots of hard work makes it difficult to accomplish the mission." [said of COMBAT EDGE]

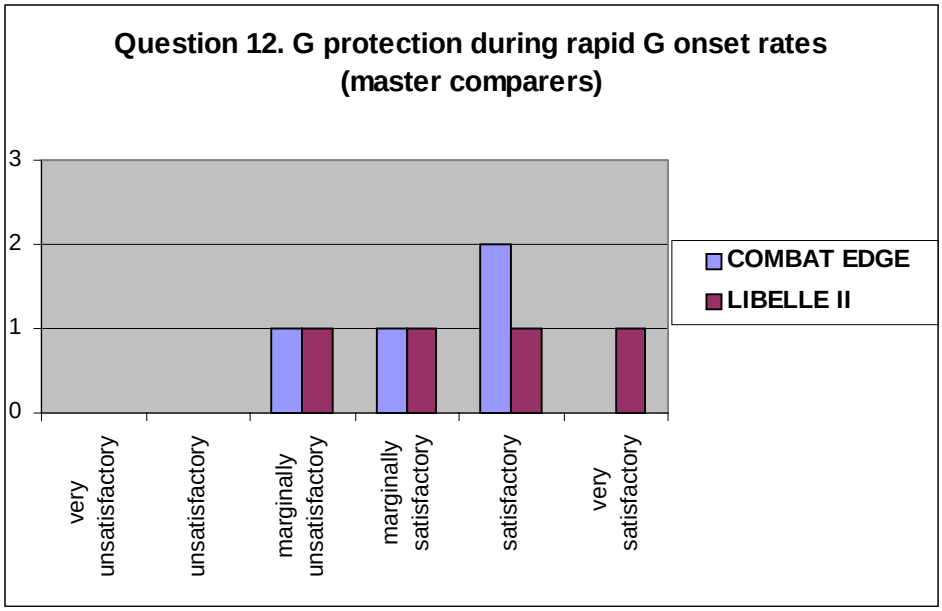

Figure 13. Subjects slightly preferred the LIBELLE and rated it barely satisfactory on rapid G onset rates.

Just looking at the red (LIBELLE II) bars reveals that on an absolute scale, the LIBELLE II was rated much lower than ratings on any other utility question. It can also be seen that the COMBAT EDGE faired almost equally poorly, except for one master comparer who bumped the LIBELLE II up by one category.

Considering and including earlier flights of the master comparers would have little effect on results. Including the other four subjects (comparers but not qualified to be "masters") would have raised the average score slightly.

Results are moderately better than the HAVE LIBELLE results.

Amplifying comment:

- "Still must pre-strain or I get light loss."

Fatigue

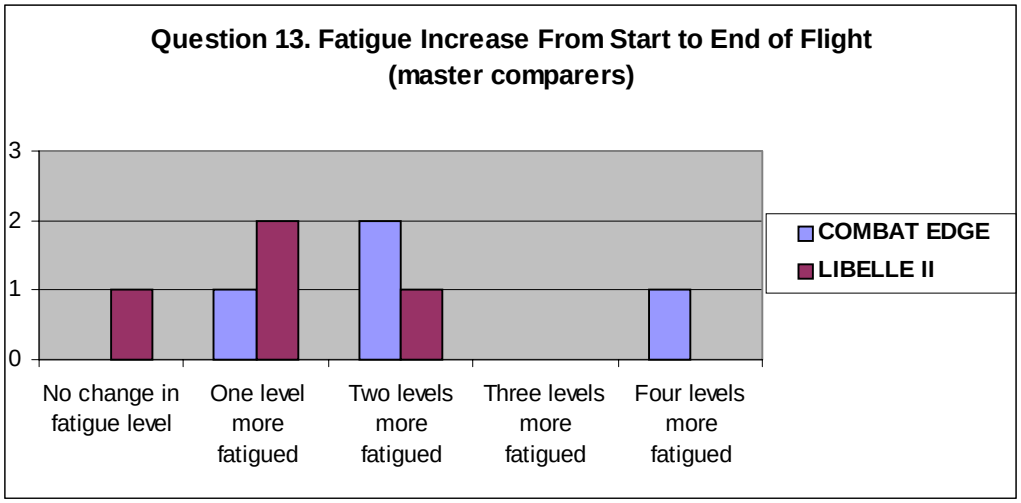

Figure 14. Subjects were less fatigued after a LIBELLE flight.

Pilots often commented that the biggest difference in the COMBAT EDGE and the LIBELLE II is the difference in fatigue level after flight. Fatigue levels were assessed immediately before and after flight using a seven-point subjective fatigue scale. The results are as shown.

The mean change in fatigue level using the LIBELLE II was one fatigue unit and the mean fatigue change using the COMBAT EDGE was two and a quarter fatigue units; therefore, the COMBAT EDGE subjects experienced a greater change in fatigue due to the high-G flight, which is, of course, a change toward more fatigue. It appeared that recovery time between sorties and even between high-G events (from listening to the pilots) was much less using the LIBELLE II. This difference could translate to quicker turn-around times for pilots wearing the LIBELLE II.

The fact that the LIBELLE II was generally rated better (or to the left of COMBAT EDGE in this particular chart) indicates that the LIBELLE II was generally rated above the COMBAT EDGE. Considering and including earlier flights of the master comparers would not have appreciable effect on results. Including the other four subjects who were comparers, but not qualified to be “masters” (they did not have a recent flight in the COMBAT EDGE with a completed questionnaire to use) would not have had an appreciable effect on results. These results are essentially the same as the HAVE LIBELLE test.

In summary, the Libelle II ranked above the COMBAT EDGE in anti-G protection (all categories therein) with a median score of satisfactory in all categories. Some particular strengths were: ability to accomplish mission in high-G environment, verbal communication at high-G, and workload at high-G.

Ease of Donning

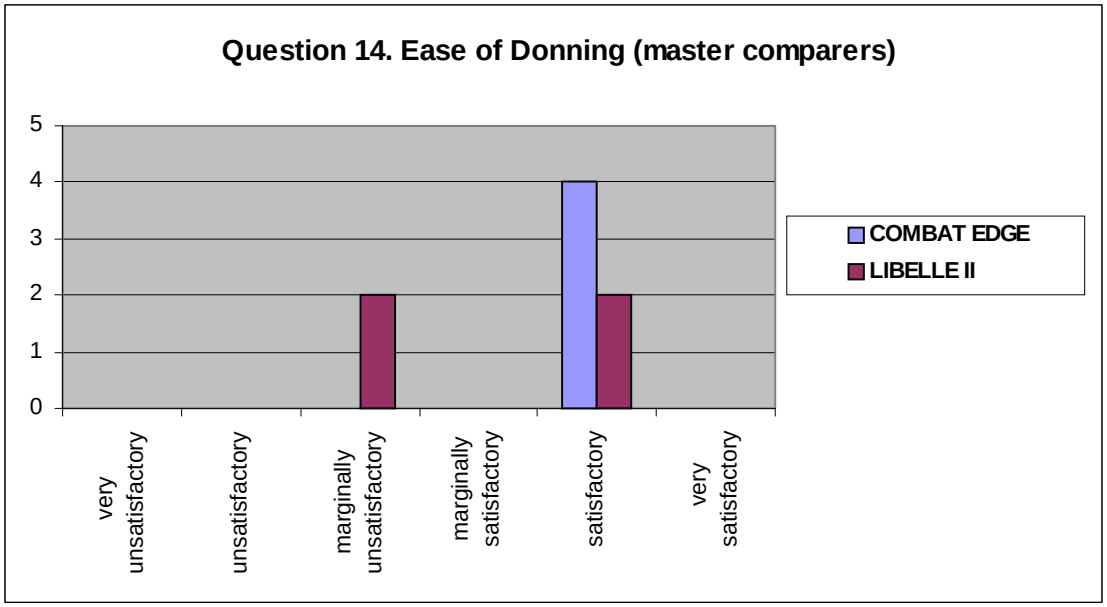

Figure 15. Subjects preferred the COMBAT EDGE and rated the LIBELLE marginally satisfactory for ease of donning.

A glance at the chart reveals that the LIBELLE II is rated low for donning even with the help (physical help as in an old-fashioned valet) of the manufacturer's representative. Also, it is clearly inferior to the COMBAT EDGE standard. Two master comparers rated it two categories worse than the COMBAT EDGE. It took about seven minutes to don the LIBELLE II, whereas the COMBAT EDGE took about two or three minutes.

Considering and including earlier flights of the master comparers would have little effect on results. Including the other four subjects (comparers but not qualified to be "masters") would have raised the average score.

Results are moderately less positive than the HAVE LIBELLE results.

Ease of Doffing

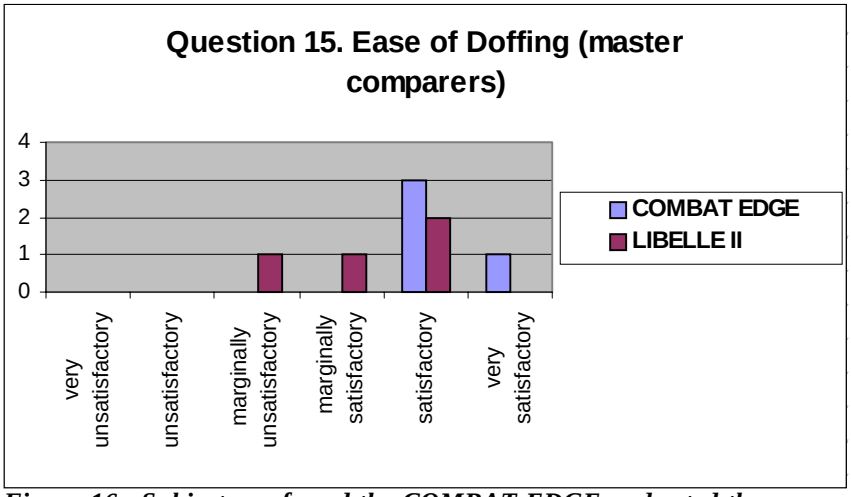

Figure 16. Subjects preferred the COMBAT EDGE and rated the LIBELLE marginally satisfactory for ease of doffing.

A glance at the chart reveals that the LIBELLE II is rated low in doffing (but not as low as donning). Also, it is clearly inferior to the COMBAT EDGE standard. Two master comparers rated it one category worse than the COMBAT EDGE, and one rated the LIBELLE II two categories worse. It took only one or two minutes to doff, which is about the same as the COMBAT EDGE. Considering and including earlier flights of the master comparers would have little effect on results. Including the other four subjects (comparers but not qualified to be "masters") would have raised the average score dramatically.

Results are moderately less positive than the HAVE LIBELLE results.

Ability to Flex and Extend Lower Body

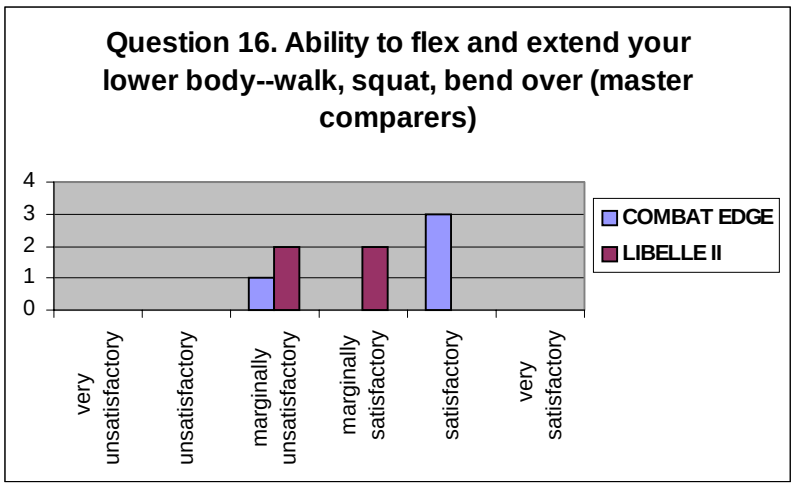

Figure 17. Subjects deemed the LIBELLE marginal in flexing and extending lower body, and inferior to the COMBAT EDGE.

A glance at the chart reveals that the LIBELLE II is rated low in lower body flexibility. Also, it is clearly inferior to the COMBAT EDGE standard. Two master comparers rated it one category worse than the COMBAT EDGE and one rated the LIBELLE II two categories worse. Considering and including earlier flights of the master comparers would have made the average score even lower. Including the other four subjects (comparers but not qualified to be "masters") would have little effect on the average score.

Results are slightly better than the HAVE LIBELLE results.

Amplifying comments were:

- "Really had to step into van." [Referring to the crew van that brought the pilots to the aircraft].

Ability to Perform Aircraft Preflight

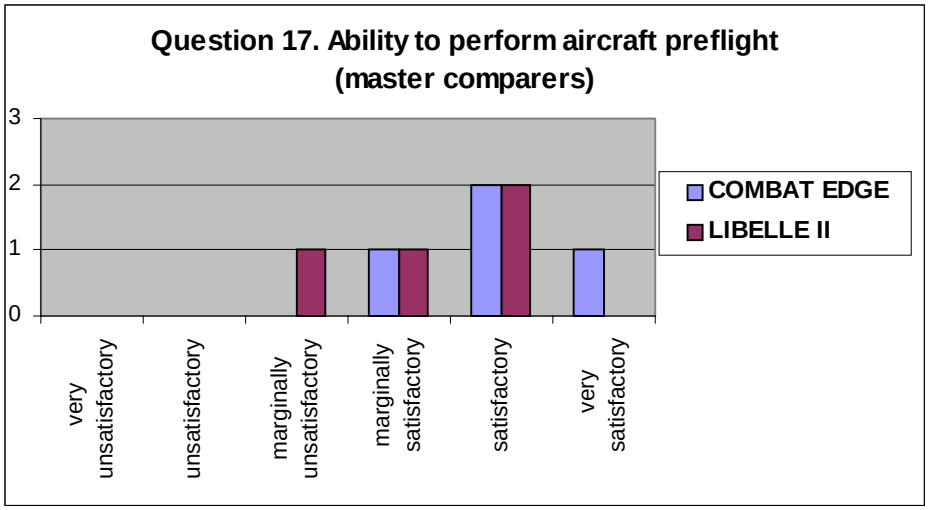

Figure 18. Subjects deemed the LIBELLE marginal to satisfactory in aircraft preflight, and inferior to the COMBAT EDGE.

A glance at the chart reveals that the LIBELLE II is rated low in ability to perform aircraft preflight. Pilots had particular difficulty inspecting wheel wells (as noted by observing the pilots). Also, it is clearly inferior to the COMBAT EDGE standard. Three master comparers rated it one category worse than the COMBAT EDGE and one rated the LIBELLE II two categories worse. Considering and including earlier flights of the master comparers would have made the average score even worse. Including the other four subjects (comparers but not qualified to be "masters") would little effect on the average score.

Results are slightly more positive than the HAVE LIBELLE results.

Ease of Climbing into the Cockpit

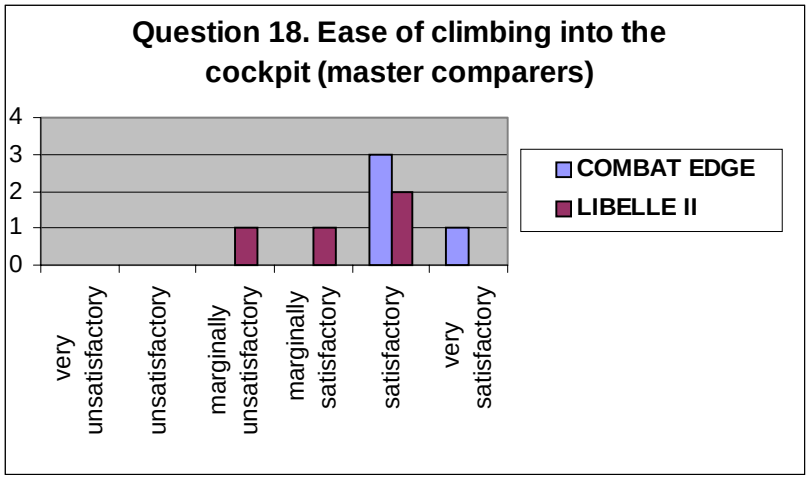

Figure 19. Subjects rated the LIBELLE marginal to satisfactory for climbing into cockpit and inferior to COMBAT EDGE.

A glance at the chart reveals that the LIBELLE II is rated low in ease of climbing into the cockpit. One should note that the F-16 cockpit is particularly difficult to climb into. Also, it is clearly inferior to the COMBAT EDGE standard. Two master comparers rated it one category worse than the COMBAT EDGE, and one rated the LIBELLE II two categories worse. Considering and including earlier flights of the master comparers would have made the average score lower. Including the other four subjects (comparers but not qualified to be "masters") would also have made the average score even lower.

Results are moderately better than the HAVE LIBELLE results.

Ability to Reach Cockpit Controls

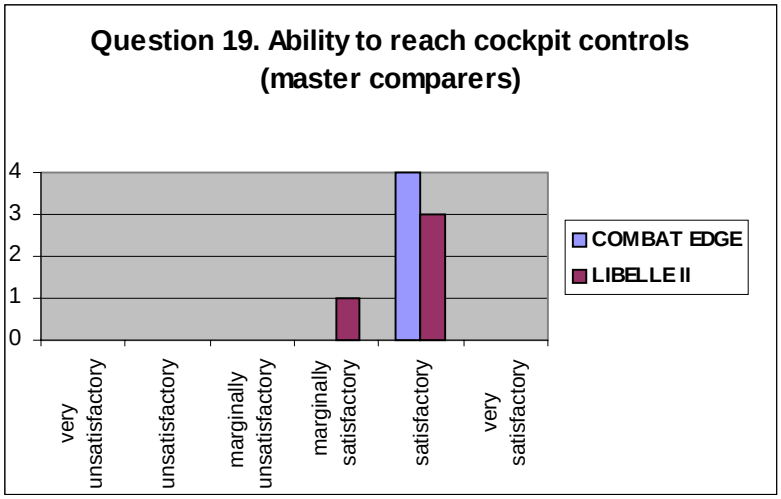

Figure 20. Subjects rated the LIBELLE satisfactory but slightly inferior to COMBAT EDGE for ability to reach cockpit controls.

A glance at the chart reveals that the LIBELLE II is rated slightly low in ability to reach aircraft controls. Also, it is slightly inferior to the COMBAT EDGE standard. One master comparer rated it one category worse than the COMBAT EDGE. Considering and including earlier flights of the master comparers would have made the average score slightly worse. Including the other four subjects (comparers but not qualified to be "masters") would have raised the average score but also would have added an "unsatisfactory." Pilots were heard to complain about bumping the stick with their forearm in the F-16 when trying to reach past the stick to toggle a check-fuel switch.

Results are slightly less positive than the HAVE LIBELLE results.

Ease of Connecting Hoses and Performing PRICE Check

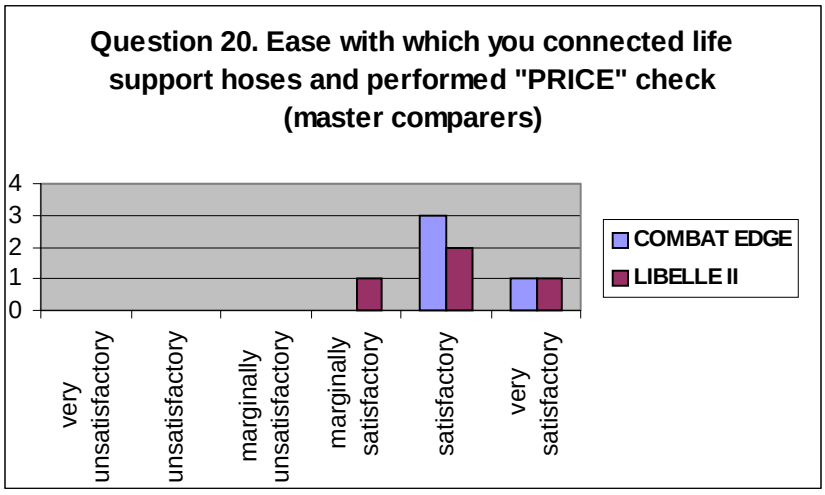

Figure 21. Subjects rated LIBELLE satisfactory for connection of life support hoses, which was only slightly inferior to COMBAT EDGE.

A glance at the chart reveals that the LIBELLE II is rated just slightly low in ability to connect to pilot umbilicals. Also, it is slightly inferior to the COMBAT EDGE standard. One master comparer rated it one category worse than the COMBAT EDGE. Considering and including earlier flights of the master comparers would have made the average score slightly worse. Including the other four subjects (comparers but not qualified to be "masters") would have raised the average score.

Results are essentially the same as the HAVE LIBELLE results.

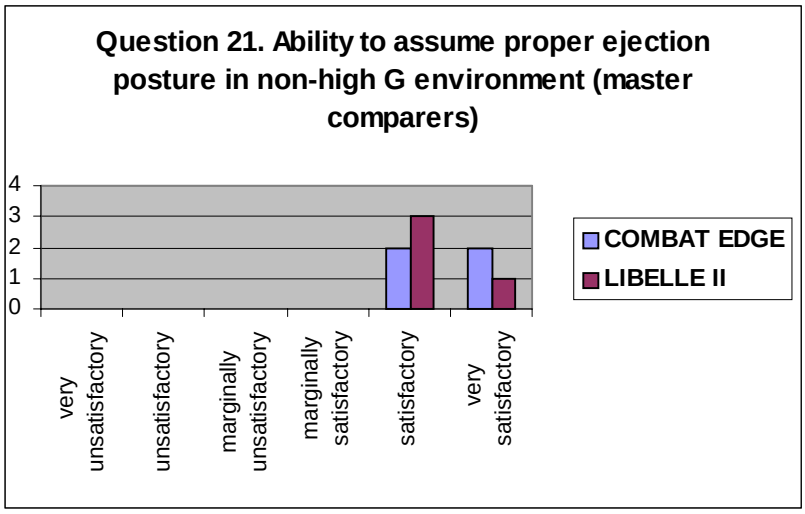

Figure 22. Subjects rated the LIBELLE satisfactory for ejection posture, but slightly inferior to COMBAT EDGE.

A glance at the chart reveals that the LIBELLE II is rated quite satisfactory in ability to assume proper ejection posture. Also, it is slightly inferior to the COMBAT EDGE standard. One master comparer rated it one category worse than the COMBAT EDGE. Considering and including earlier flights of the master comparers would have made the average score slightly better. Including the other four subjects (comparers but not qualified to be "masters") would have little effect on the average score.

Results are essentially the same as the HAVE LIBELLE results.

It is important to note that these results are reasoned judgement—not results of ejection tests.

Ability to "Check six."

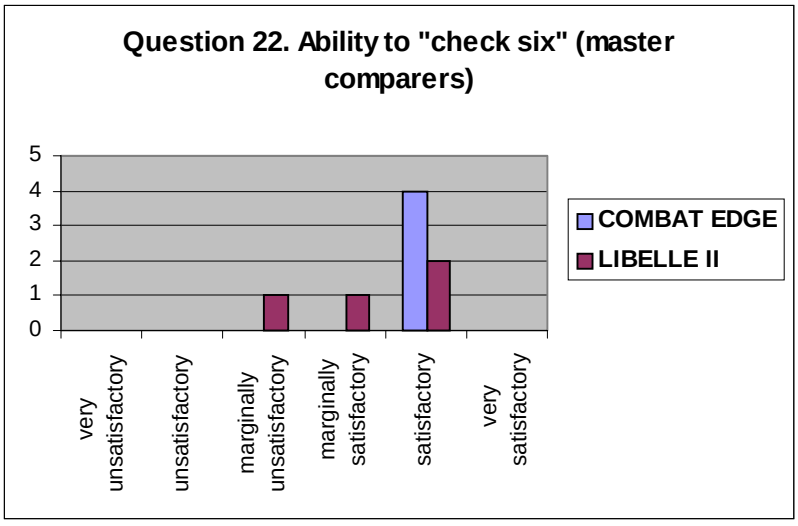

Figure 23. Subjects rated the LIBELLE marginal to satisfactory for ability to "Check six."

A glance at the chart reveals that the LIBELLE II is rated somewhat low in ability to look around behind to check for an adversary. Also, it is clearly inferior to the COMBAT EDGE standard. One master comparer rated it one category worse than the COMBAT EDGE and one rated the LIBELLE II two categories worse. Considering and including earlier flights of the master comparers would have made the average score even lower. Including the other four subjects (comparers but not qualified to be "masters") would make the average score slightly better.

Results are moderately worse than the HAVE LIBELLE results.

Overall Mobility

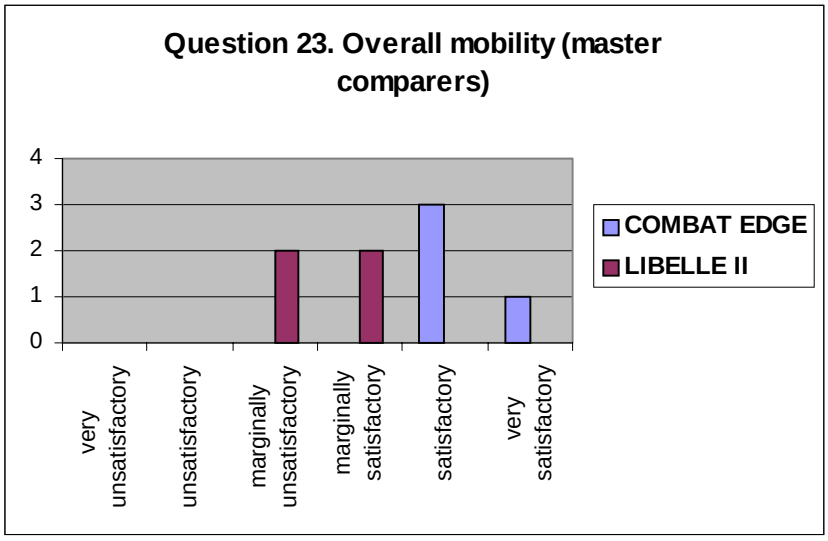

Figure 24. Subjects rated the LIBELLE purely marginal and clearly inferior to COMBAT EDGE for overall mobility.

A glance at the chart reveals that the LIBELLE II is rated low in overall mobility. Also, it is clearly inferior to the COMBAT EDGE standard. Three master comparers rated it two categories worse than the COMBAT EDGE and one rated the LIBELLE II one category worse. Considering and including earlier flights of the master comparers would have made the average score even worse. Including the other four subjects (comparers but not qualified to be "masters") would raise the average score and add one "very satisfactory."

Results are slightly better than the HAVE LIBELLE results.

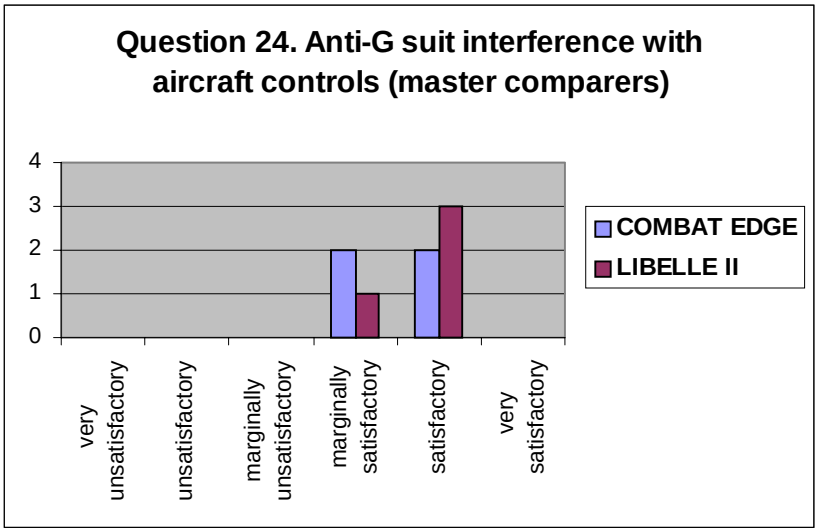

Figure 25. Subjects rated the LIBELLE marginal to satisfactory for interference with aircraft controls, and superior to COMBAT EDGE.

A glance at the chart reveals that the LIBELLE II is rated basically satisfactory (low in interference) with aircraft controls. Also, it is slightly superior to COMBAT EDGE standard. One master comparer rated the LIBELLE II one category better than the COMBAT EDGE. Subjects did not write down what caused low COMBAT EDGE scores. Considering and including earlier flights of the master comparers would have made the average score worse. Including the other four subjects (comparers but not qualified to be "masters") would have raised the average score dramatically.

Results are slightly better than the HAVE LIBELLE results.

Amplifying comments were:

- "Thick arms cause problems sometimes. Need pockets too."
- "Left roll occurred every time I checked the fuel. Consider removing arms from G-suit."
- "Last flight, [I] hit stick on F-16 while checking fuel."

It is not clear what caused the lower ratings on the COMBAT EDGE, since pilots did not verbally complain about COMBAT EDGE except for one comment: left G-suit hose interferes with trim panel.

Overall Comfort at One G

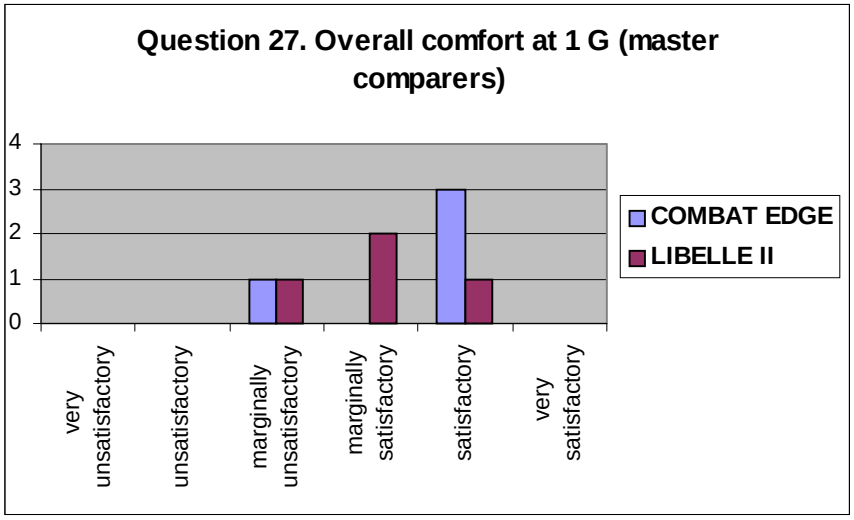

Figure 26. Subjects rated the LIBELLE marginally satisfactory for overall comfort at one G, and inferior to COMBAT EDGE.

A glance at the chart reveals that the LIBELLE II is rated slightly low in overall comfort at one G. Also, it is slightly inferior to the COMBAT EDGE standard. Two master comparers rated it one category worse than the COMBAT EDGE and one rated the LIBELLE II two categories worse. Considering and including earlier flights of the master comparers would have made the average score worse. Including the other four subjects (comparers but not qualified to be "masters") would raise the average score.

Results are essentially the same as the HAVE LIBELLE results.

Amplifying comments were:

- "Cumbersome and a bit restrictive, particularly at the knee."

In fairness, most subjects commented off-line that the LIBELLE II was cooler than the COMBAT EDGE.

Overall Comfort at Sustained High-G

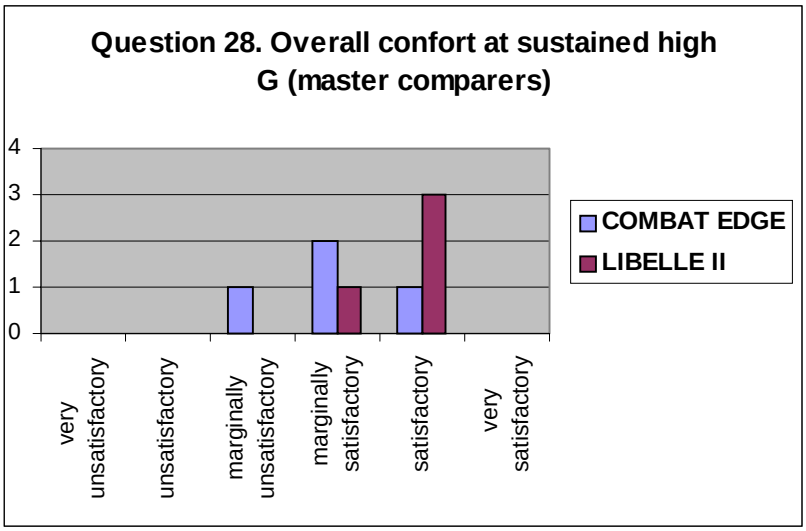

Figure 27. Subjects rated the LIBELLE satisfactory and clearly superior to COMBAT EDGE at high-G.

A glance at the chart reveals that the LIBELLE II is rated high in overall comfort at high-G. The subjects may have interpreted this question as a utility and not as a suitability question. That is, in general, increased comfort translates to ability to fight better, but that statement would be particularly true at high-G. Also, it is clearly better than the COMBAT EDGE standard. One master comparer rated it one category better than the COMBAT EDGE and one rated the LIBELLE II two categories better. Considering and including earlier flights of the master comparers would have made the average score a little worse. Including the other four subjects (comparers but not qualified to be "masters") would raise the average score.

Results are slightly better than the HAVE LIBELLE results.

Amplifying comments were:

- "Do not notice that it is on at high G."

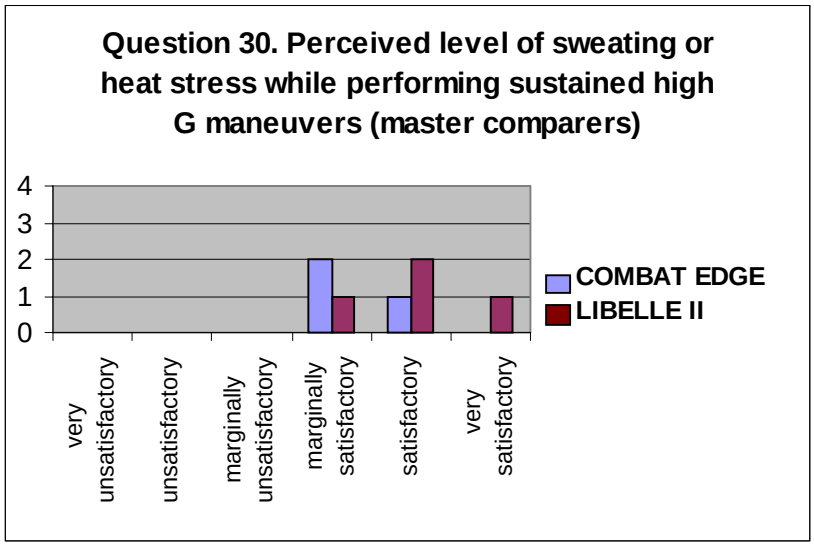

Figure 28. Subjects deemed the LIBELLE quite satisfactory for heat stress and superior to COMBAT EDGE.

The fact that most of the LIBELLE II suit is constructed of at least a somewhat permeable material shows in these results (Figure 29). Edwards AFB experienced high temperatures (often over 100 degrees) for the duration of the flight test. Also, the liquid that "powers" the LIBELLE II was chilled for some flights which tended to keep the pilot cool for the first half of the flight.

The chart shows that the LIBELLE II was rated at least marginally satisfactory by all subjects, and highest so far among the suitability questions. Three of the four master comparers rated it at least one category better than the COMBAT EDGE with one rating it one category worse. Considering and including earlier flights of the master comparers would not have an appreciable effect on results. Including the other four subjects (most of which tried the cool water) would have made the results even more positive.

Results were slightly more positive than HAVE LIBELLE tests.

Amplifying comments were:

- "Not hot." [this comment said it all]

Figure 29. Sweat Marks: Sweat marks emphasize that most of the suit area's permeable material decreases sweat retention. Sweat is evaporated in all areas except for the strip just beneath the liquid-filled tube.

Ability to Fly at a Desired G Load

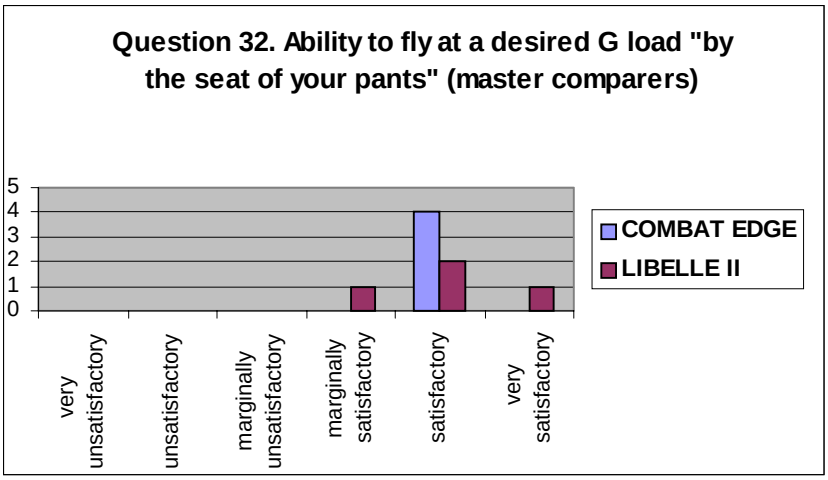

Figure 30. The subjects rated the LIBELLE satisfactory and equivalent to COMBAT EDGE for ability to fly at desired G load.

The chart shows that LIBELLE II was rated at least marginally satisfactory by all subjects, with a much higher variance than the COMBAT EDGE results. One could speculate that with more experience, the pilots might have rated the suit better. Considering and including earlier flights of the master comparers would not have an appreciable effect on results. Including the other four subjects would have made the results the same on average but with lower variance.

Results were almost exactly the same as HAVE LIBELLE tests. Amplifying comments were:

- "learned" [said by two subjects, meaning apparently that they learned to gage the LIBELLE G-suit]

Anti-G Suit Safety for Operational Use

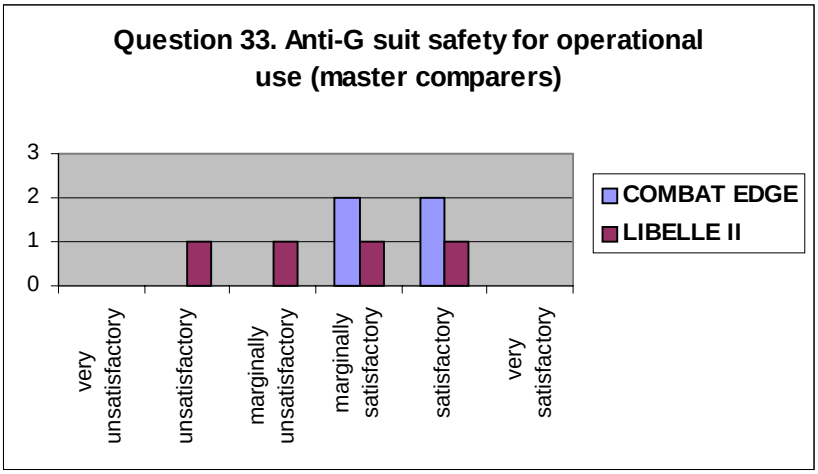

Figure 31. Subjects rated the LIBELLE marginal and inferior to COMBAT EDGE for anti-G suit safety for operational use.

The chart shows that LIBELLE II was rated all over the chart. Two of the four master comparers rated it worse than the COMBAT EDGE. Including earlier flights or expanding beyond the master comparers would not have changed the results much.

Results were essentially the same as HAVE LIBELLE tests.

Amplifying comments were:

- "Needs to be easier to don and doff and less mobility restrictive."
- "Comfort/mobility." [the subject must have meant that comfort and mobility was bad enough to be a safety issue]
- "Ground operations still unsat, not enough flex."

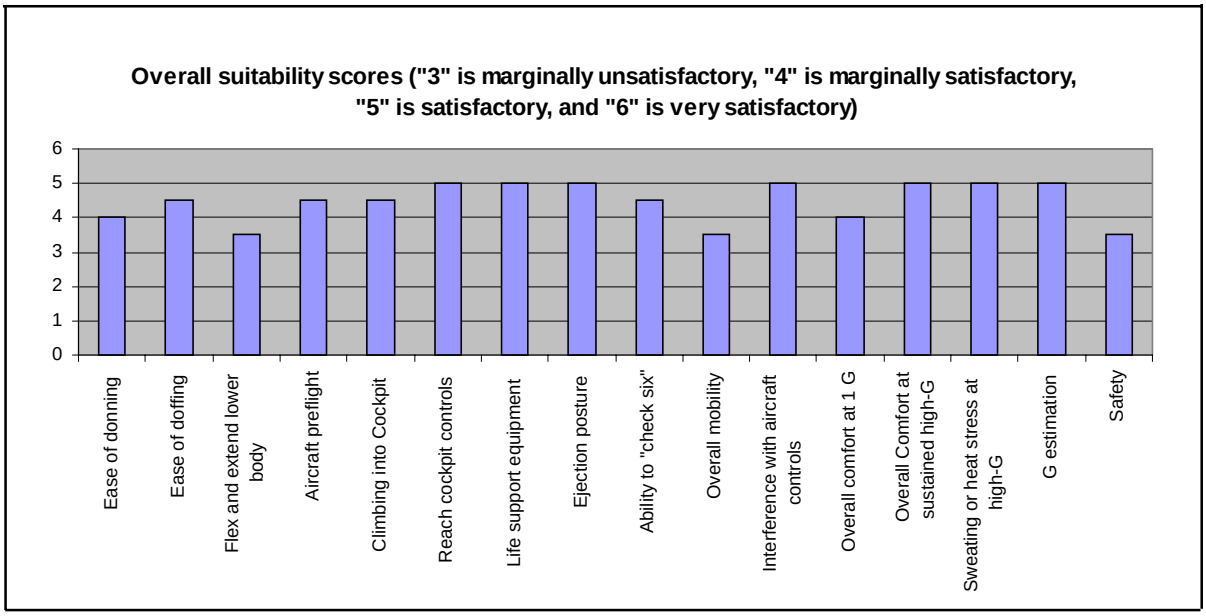

Figure 32. Overall suitability scores.

To summarize suitability issues, one can say that the LIBELLE II was somewhat poor or at least subordinate to the COMBAT EDGE standard in ability to preflight the aircraft, ease of climbing into the cockpit, ability to reach cockpit controls, ability to connect life support hoses and perform a price check, ability to "check six," overall mobility (most marginal score), overall comfort at one G, and safety for flight. The 'comfort at high-G' question in the Suitability category gave good results, as did the 'interference with aircraft controls' question. One can summarize that the LIBELLE II is superior at high-G and inferior at low-G. How do the subjects feel about the one-G/multi-G trade-off? This subject is covered in the next section.

Overall Opinion of Anti-G Suit Worn

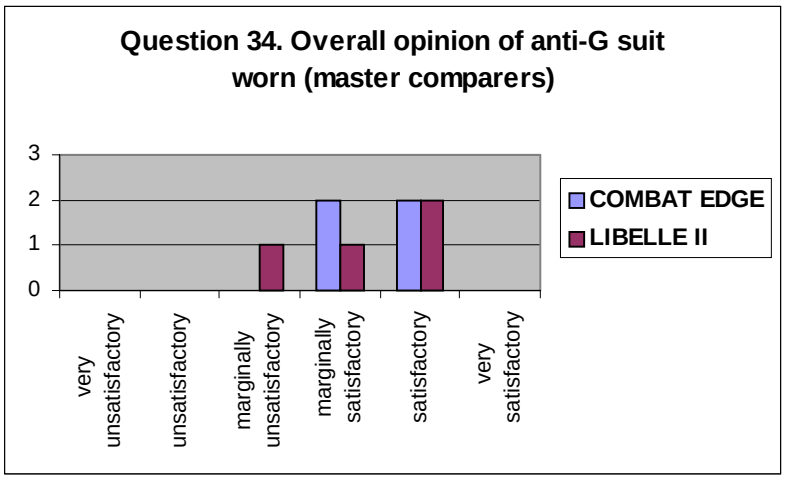

Figure 33. Overall opinion of anti-G suit.

As stated earlier, the overall comparison question is theoretically and practically difficult. Answers to this one question (rather than a summary of discussion and comments) say that the G-suits are basically equivalent. Including earlier flights or including the non-masters (who did not necessary ever fly in and thus rate the COMBAT EDGE) would not change the results much.

These results were slightly less positive than HAVE LIBELLE results.

Comments were as follows:

- "Great for high G not great for mobility but different g-strain requires training/understanding."
- "Tried both loose and tight lap belt configurations. G-suit performed noticeably better today than previous flight [previous flight subject pinched LIBELLE tube with aircraft safety belt]. Was able to strain & [and sustain] 9 G then relax for 2-3 second periods before straining again."
- "Impact: Little advantage in current generation fighters that bleed energy below 9G [but] capable in 1st 180 degrees [degrees of turn]. Future generation A/C may reap the benefit of being able to take short breaks in strain @ 9Gs. Also noted knee pain following each sortie. Pain located in both knees at kneecap. Pain disappeared after walking for 5-10 min. Shoulder straps consistently slipped behind back instead of [at the] shoulder."
- "Verbal communication with LIBELLE under high-G conditions most impressive. Very hot outside [even though it was hot outside] seems cooler than COMBAT EDGE."

- "One G mobility and weight are primary detractors."
- "No pen or pencil holder."
- "Saw the G god." [this was the subject's way to express that the fact that he was particularly impressed by the LIBELLE II. Also, the fact than an improper AGSM hampered him on earlier flights, but problem was over now]
- "Can talk, think and fight at 9 G for longer in LIBELLE than in edge. Suitability is 'not as good' due to mobility restrictions."
- "Personally, I see no noticeable increase in G–tolerance. Workload may decrease once new straining technique is perfected. However, restricted mobility and added weight do not justify the small (if any) improvement in performance."
- "Yes, when functioning and used properly, ability to relax and talk at high G's with less fatigue could be very significant. As long as operational/mobility integration acceptance issues are answered or covered."
- "Must have pocket for parachute knife. We should not fly again without knife.

As mentioned before in the description, the LIBELLE II has a lower and upper body part. In each case, the entire G-suit was worn by an individual subject; however, one excursion was attempted in which a subject put *on just the top* of the LIBELLE II in combination with the CSU-13 B/P. The subject reported little to no arm pain in the high-G mission and amplified this remark by stating that he has always previously experienced arm pain at high-G (he called the chronic pain his "dirty little secret," and was ecstatic about no pain).

Relative Costs

311 HSW/YA estimates that after development and procurement of the LIBELLE anti-G system, about five million dollars per year would be saved annually in sustainment costs over the COMBAT EDGE technology. The savings would primarily be due to elimination of costs associated with maintenance and replacement of G valves, G hoses, and pressure breathing regulators required for the COMBAT EDGE system. Refer to Appendix D for details.

CONCLUSIONS AND RECOMMENDATIONS

All Project LIBELLE II test objectives were met. The LIBELLE II G-suit was considered ***HIGH SATISFACTORY*** for anti-G protection and ***MARGINAL*** for flight suitability. The advertised advantages of LIBELLE II were substantiated by this series of tests except for the claims that LIBELLE II offered improved anti-G protection during rapid G onset rates.

The LIBELLE II G-suit, to almost all pilots, offers the following:

- slightly better G protection
- significantly less fatigue after very high-G maneuvers
- better ability to communicate during high-G

These are tremendous advantages for any G-suit. It is reasonable to conclude that these advantages could translate to improved combat effectiveness of the fighter pilot, particularly in the air-to-air role. For example, a pilot who is more alert and has to concentrate less on accomplishing an AGSM would have at least a slight advantage in the high-G air-to-air fight. The pilot can talk more clearly in the LIBELLE II. Clear communication can be critical for "break" calls and for "clock" positions of "bogies" or enemy aircraft. Also, the ability to reschedule the same pilot for a quicker turnaround would probably improve with a LIBELLE-type system.

Also, a suit that offers better G tolerance could reduce incidents and catastrophes due to G-lock; however, the suit in its current state has definite suitability problems:

- special training required for use
- undesirable for everyday wear

One pilot is on record for stating that despite the increased G protection, he would not like the suit for day-to-day wear. This pilot also said that he does not expect to spend enough time at very high-G to make it worth the effort to put up with the suitability problems of the current LIBELLE II flight suit. However, this prototype was more comfortable and suitable than one developed and worn in March 2000 during the HAVE LIBELLE flight tests; therefore, the SAGE has established a track record of continuous improvement and we expect further development to continue.

Given the evidence that LIBELLE II provides better G protection—a tactical advantage in pilot performance under G—and reduced sustainment costs (five million less than COMBAT EDGE per year), this technology *should be pursued* for the next generation of AF life support equipment.

APPENDIX A Acronyms

AEF	Aerospace Expeditionary Force
AEFB	Aerospace Expeditionary Force Battlelab
AERP	Aircrew Eye/Respiratory Protection
AFB	Air Force Base
AFFTC	Air Force Flight Test Center
AFI	Air Force Instruction
AFOTEC	Air Force Operational Test and Evaluation Center
AFRL	Air Force Research Lab
AFSC	Air Force Specialty Code
AGL	Above Ground Level
AGSM	Anti-G Straining Maneuver
ANG	Air National Guard
BFM	Basic Fighter Maneuvers
CIDS	Critical Item Development Specification
CSU 13B/P	Operational Anti-G Suit
Det 1	Detachment One
$+G_z$	Positive Acceleration
HSW	Human Systems Wing
LSS	Life Support Systems
MOE	Measure of Effectiveness
MOP	Measure of Performance
MSL	Mean Sea Level (above)
MTBF	Mean Time Between Failure
MTTR	Mean Time to Repair
OJT	On-Job-Training
Ops Tempo	Operating Tempo
PA	Pressure Altitude
PLF	Parachute Landing Fall
PQDR	Product Quality Defiency Report
SAGE	Self-Regulated Anti-G Ensemble
SAR	Search and Rescue
TPS	Test Pilot School

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APPENDIX B LIBELLE II System Description

The LIBELLE II suit is composed of a Nomex/Kevlar outer shell, with silk/cotton, or pure cotton undergarments. The suit is equipped with fluid-filled tubing, which allows hydrostatic pressure to increase at the lower extremities of the body when exposed to increased acceleration loads, tightening the fabric around the wearer. This tightening creates a G-compensating pressure against the skin. Because the suit is based on liquid pressurization, it does not significantly increase in size under G-loading, which is different than current pneumatically-pressurized suits. Unlike previous hydrostatic suits and most pneumatic suits, the LIBELLE II suit fabric is breathable, because the fluid was limited to tubes instead of large bladders that covered the majority of the body. This permits body cooling by means of evaporative heat loss when sweating. The suit is also unique in that it was worn in lieu of a flight suit, compared to most conventional suits that are worn over the flight suit. As a prototype, the suit lacked many of the features that would be required of an operational ensemble, such as pockets, collar, penholders, and size adjustments.

Advertised advantages of the suit include the following:

- More immediate response
- No shifting of organs due to localized pressure application
- Skeletal and muscular relief
- No pressure breathing required
- Unimpeded speech
- Significant delay of “tunnel vision” and no “gray out”
- Major reduction in required G-straining maneuvers
- Protection from negative G-loading

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APPENDIX C Test Cards with Questionnaires

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DATE:	LIBELLE II: F-16B Suit/Aircrew Compatibility	STEP / TO
28 Jul 00		/

CALLSIGN	AIRCREW	OPS #	TAIL #

Configuration / Date	T/O GW (ZERO FUEL WT)	T/O CG	MSN FREQ

WX/NOTAMS	LAKEBEDS	TEMP / P A

ACCEL	ROTATE	T/O	T/O DIST	IMMED APP	DIST	APP SPEED

SFO	JOKER	BINGO
/ /		

TEST LIMITS:
G: Aircraft flt man limits
Alt: ≤ 25K ft PA (No FTTs/aerobatics < 5000'AGL)
A/S: w/ centerline, 600 KCAS / 1.6M
Total number of High G maneuvers will be IAW AFFTCI 11-1, Paragraph 15.7.

- No more than 8 sustained 7+ G test points above 5 sec
- No more than 16 short duration 7+ G test points

PROFILE:

1. Ground Operations/Takeoff
2. Altitude investigation – climb to 25K ft PA (pressure changes, mobility, comfort)
3. G Awareness Ex – 90° turn @ 5G, 180° turn @ 5-7G
4. Medium Altitude, PCU Check Turns – 2G, 3G, 4G, 5G
5. Aerobatics evaluation – (interference, G estimation)
6. Break turn evaluation – break turns up to the test limit (rapid G onset, mobility)
7. Sustained High G & Negative G Evals
8. Landing

GO / NO-GO:
1. 1 good jet

TAKE ALONG:
1. HUD Tape
2. Line Badge
3. Water Bottle
4. Ear Plugs

NOTES

EMERGENCY PROCEDURES	Card EP

ZIPPER BLOWOUT
Terminate Maneuver
If main zipper blowout > 3 inches ⇒ RTB
If main zipper blowout < 3 inches ⇒ Pilot's decision to continue

LIQUID LEAKS
Terminate Maneuver
Verify liquid levels between events
If levels too low/or leak evident ⇒ RTB

CONTROLLED EJECTION
Disconnect pressure gauges if possible

EMERGENCY GROUND EGRESS
Unzip main and upper leg zippers (time permitting)
Disconnect pressure gauges if possible

NEXT MANEUVER: GROUND OPS/TAKEOFF

GROUND OPERATIONS/TAKEOFF — Card 1

LIMITS CANOPY: 50 KIAS

PREFLIGHT

Fatigue level immediately before flight:

1 - Fully Alert; Wide Awake; Extremely Peppy
2 - Very Lively; Responsive, But Not At Peak
3 - Okay; Somewhat Fresh
4 - A Little Tired; Less Than Fresh
5 - Moderately Tired; Let Down
6 - Extremely Tired; Very Difficult to Concentrate
7 - Completely Exhausted; Unable to Function Effectively; Ready to Drop

ENGINE START

COMFORT

BEFORE TAXI CHECKS

TAXIING

Brakes easy to reach quickly?

TOLD REVIEW: MACS _____ ROT _____ T/O _____

[ ] DATA ON

TAKEOFF

Temp _____ Fuel _____/_____
PA _____ Time _____
Wind _____/_____

OTHER COMMENTS:

NEXT MANEUVER: ALTITUDE INVESTIGATION

ALTITUDE INVESTIGATION — Card 2

Entry/Test Conditions:	Configuration:
Takeoff to 25K ft PA	
Data Band/Tolerances:	Limits:
25K +0/-200 ft PA	< 25K ft MSL

[ ] CHECK WATER LEVELS

CABIN PRESSURE CHANGES

COMMENTS:

COCKPIT COMPATIBILITY

A. Switchology
B. Mobility

COMMENTS:

NEXT MANEUVER: G_z AWARENESS EXERCISE

G_z AWARENESS EXERCISE	Card 3
Entry/Test Conditions:	Configuration:
Data Band/Tolerances: 8 - 23 KFT MSL	Limits: > 5KFT AGL, < 25K ft MSL

[ ] CHECK WATER LEVELS

90° turn @ 5G

180° turn @ 5-7G

COMMENTS:

NEXT MANEUVER: MED ALTITUDE, PCU CHECK TURNS

MED ALTITUDE, PCU CHECK TURNS	Card 4
Entry/Test Conditions:	Configuration:
Data Band/Tolerances: 8 - 23 KFT MSL	Limits: > 5 KFT AGL, < 25 KFT MSL

[ ] CHECK WATER LEVELS

HOLD DESIRED Gz for 10 Secs

$2G_z$ Turn:	
$3G_z$ Turn:	
$4G_z$ Turn:	
$5G_z$ Turn	

COMMENTS:

NEXT MANEUVER: AEROBATIC EVALUATION

AEROBATIC EVALUATION — Card 5

Entry/Test Conditions:	Configuration:
Data Band/Tolerances:	Limits: > 5KFT AGL, < 25K ft MSL

[ ] CHECK WATER LEVELS

INTERFERENCE

G ESTIMATION

Wind-Up Turn

Aileron Roll

Barrel Roll

Loop

Immelman

Split-S

[ ] Fuel: _____

NEXT MANEUVER: BREAK TURN EVALUATION

BREAK TURN EVALUATION — Card 6

Entry/Test Conditions: 450 KCAS	Configuration:
Data Band/Tolerances:	Limits: > 5KFT AGL, < 25K ft MSL

[ ] CHECK WATER LEVELS

RAPID G ONSET

MOBILITY

CHECK 6

COMMENTS:

[ ] Fuel: _____

NEXT MANEUVER: SUSTAINED HIGH G & NEG G EVALS

SUSTAINED HIGH G & NEG G EVALS | Card 7a

Entry/Test Conditions:	Configuration:
Data Band/Tolerances: 8 - 23 KFT MSL	Limits: > 5 KFT AGL, < 25 KFT MSL

[ ] CHECK WATER LEVELS

Max G turn > 720°

Workload required during high-G maneuvers on this flight:

_____ Minutes at this workload level

6 – No exertion at all
7 – Extremely light
8
9 – Very light
10
11 – Light
12
13 – Somewhat hard
14
15 – Hard / Heavy
16
17 – Very hard
18
19 – Extremely hard
20 – Maximum exertion

NEGATIVE G PUSH (10 SEC) – after last High G Eval

[ ] Fuel: _____

Joker _____ Bingo _____

NEXT MANEUVER: CONTINUE HIGH G EVAL (fuel permitting)

SUSTAINED HIGH G EVALUATION | Card 7b

Entry/Test Conditions:	Configuration:
Data Band/Tolerances: 8 - 23 KFT MSL	Limits: > 5 KFT AGL, < 25 KFT MSL

[ ] CHECK WATER LEVELS

Max G turn > 720°

Workload required during high-G maneuvers on this flight:

_____ Minutes at this workload level

6 – No exertion at all
7 – Extremely light
8
9 – Very light
10
11 – Light
12
13 – Somewhat hard
14
15 – Hard / Heavy
16
17 – Very hard
18
19 – Extremely hard
20 – Maximum exertion

NEGATIVE G PUSH (10 SEC) – after last High G Eval

[ ] Fuel: _____

Joker _____ Bingo _____

NEXT MANEUVER: LANDING

LANDING	Card 8
Entry/Test Conditions:	Configuration:
Data Band/Tolerances:	Limits:

[ ] CHECK WATER LEVELS

Fatigue level immediately after flight:
1 - Fully Alert; Wide Awake; Extremely Peppy
2 - Very Lively; Responsive, But Not At Peak
3 - Okay; Somewhat Fresh
4 - A Little Tired; Less Than Fresh
5 - Moderately Tired; Let Down
6 - Extremely Tired; Very Difficult to Concentrate
7 - Completely Exhausted; Unable to Function Effectively; Ready to Drop

COMMENTS:

NEXT MANEUVER: MISSION COMPLETE

POST FLIGHT QUESTIONNAIRE — Card 9

Name_____ Sortie Date_____
Aircraft _____ Tail #_____ Ops #_____

Maximum positive G_z this sortie _____

How many times over 5 G_z for ≥ 5 sec? _____
How many times over 7 G_z for ≥ 5 sec? _____

Suit worn:
_____ COMBAT EDGE
_____ CSU-13 B/P
_____ LIBELLE

Aircraft: _____ T-38 _____ F-16
Cockpit: _____ Front _____ Back

Takeoff time:_____ Temp:_____

Landing time:_____ Sortie duration:_____

MOP 1.5 In Flight Anti-G Protection

1. (LIBELLE only) Comparing LIBELLE to COMBAT EDGE, rate the anti-G benefit gained from wearing the LIBELLE suit on this flight:
   - 5 - moderately better
   - 4 - barely better
   - 3 - the same
   - 2 - barely worse
   - 1 - moderately worse

   Comments:

2. Rate any gray out or tunnel vision experiences on this flight:
   - 6 - very satisfactory
   - 5 - satisfactory
   - 4 - marginally satisfactory
   - 3 - marginally unsatisfactory
   - 2 - unsatisfactory
   - 1 - very unsatisfactory

   Percent light loss:_____
   Comments:

POST FLIGHT QUESTIONNAIRE | Card 10

3. Fatigue level immediately before flight:
   - 1 - Fully Alert; Wide Awake; Extremely Peppy
   - 2 - Very Lively; Responsive, But Not At Peak
   - 3 - Okay; Somewhat Fresh
   - 4 - A Little Tired; Less Than Fresh
   - 5 - Moderately Tired; Let Down
   - 6 - Extremely Tired; Very Difficult to Concentrate
   - 7 - Completely Exhausted; Unable to Function Effectively; Ready to Drop

   Comments:

4. Fatigue level immediately after flight:
   - 1 - Fully Alert; Wide Awake; Extremely Peppy
   - 2 - Very Lively; Responsive, But Not At Peak
   - 3 - Okay; Somewhat Fresh
   - 4 - A Little Tired; Less Than Fresh
   - 5 - Moderately Tired; Let Down
   - 6 - Extremely Tired; Very Difficult to Concentrate
   - 7 - Completely Exhausted; Unable to Function Effectively; Ready to Drop

   Comments:

5. Ability to withstand sustained high G_z (fatigue tolerance):
   - 6 - very satisfactory Comments:
   - 5 - satisfactory
   - 4 - marginally satisfactory
   - 3 - marginally unsatisfactory
   - 2 - unsatisfactory
   - 1 - very unsatisfactory

6. (LIBELLE only) Comparing LIBELLE to COMBAT EDGE, rate your ability to withstand sustained high G_z:
   - 5 - moderately better Comments:
   - 4 - barely better
   - 3 - the same
   - 2 - barely worse
   - 1 - moderately worse

POST FLIGHT QUESTIONNAIRE | Card 11

7. Ability to perform the anti-G straining maneuver:
   - 6 - very satisfactory Comments:
   - 5 - satisfactory
   - 4 - marginally satisfactory
   - 3 - marginally unsatisfactory
   - 2 - unsatisfactory
   - 1 - very unsatisfactory

8. Workload required during high-G maneuvers on this flight:

   _____ Minutes at this workload level

   - 6 – No exertion at all
   - 7 – Extremely light
   - 8
   - 9 – Very light
   - 10
   - 11 – Light
   - 12
   - 13 – Somewhat hard
   - 14
   - 15 – Hard / Heavy
   - 16
   - 17 – Very hard
   - 18
   - 19 – Extremely hard
   - 20 – Maximum exertion

9. (LIBELLE only) Comparing LIBELLE to COMBAT EDGE, rate your workload required during high-G maneuvers on this flight:
   - 5 - moderately better Comments:
   - 4 - barely better
   - 3 - the same
   - 2 - barely worse
   - 1 - moderately worse

10. Ability to accomplish mission in the sustained high-G environment:
    - 6 - very satisfactory Comments:
    - 5 - satisfactory
    - 4 - marginally satisfactory
    - 3 - marginally unsatisfactory
    - 2 - unsatisfactory
    - 1 - very unsatisfactory

POST FLIGHT QUESTIONNAIRE | Card 12

11. (LIBELLE only) Comparing LIBELLE to COMBAT EDGE, rate your ability to accomplish mission in the sustained high-G environment:
    5 - moderately better Comments:
    4 - barely better
    3 - the same
    2 - barely worse
    1 - moderately worse
12. G protection during rapid G_z onset rates:
    6 - very satisfactory Comments:
    5 - satisfactory
    4 - marginally satisfactory
    3 - marginally unsatisfactory
    2 - unsatisfactory
    1 - very unsatisfactory

13. (LIBELLE only) Comparing LIBELLE to COMBAT EDGE, rate your G protection during rapid G_z onset rates:
    5 - moderately better Comments:
    4 - barely better
    3 - the same
    2 - barely worse
    1 - moderately worse

MOP 2.1 Ease of Donning and Doffing

Time to don:_____ Comments:

14. Ease of donning:
    6 - very satisfactory Comments:
    5 - satisfactory
    4 - marginally satisfactory
    3 - marginally unsatisfactory
    2 - unsatisfactory
    1 - very unsatisfactory

Time to doff:_____ Comments:

15. Ease of doffing:
    6 - very satisfactory Comments:
    5 - satisfactory
    4 - marginally satisfactory
    3 - marginally unsatisfactory
    2 - unsatisfactory
    1 - very unsatisfactory

POST FLIGHT QUESTIONNAIRE | Card 13

MOP 2.2 Aircrew Mobility

16. Ability to flex and extend your lower body (walk, squat, bend over)
    6 - very satisfactory Comments:
    5 - satisfactory
    4 - marginally satisfactory
    3 - marginally unsatisfactory
    2 - unsatisfactory
    1 - very unsatisfactory

17. Ability to perform aircraft preflight:
    6 - very satisfactory Comments:
    5 - satisfactory
    4 - marginally satisfactory
    3 - marginally unsatisfactory
    2 - unsatisfactory
    1 - very unsatisfactory

18. Ease of climbing into the cockpit:
    6 - very satisfactory Comments:
    5 - satisfactory
    4 - marginally satisfactory
    3 - marginally unsatisfactory
    2 - unsatisfactory
    1 - very unsatisfactory

19. Ability to reach cockpit controls:
    6 - very satisfactory Comments:
    5 - satisfactory
    4 - marginally satisfactory
    3 - marginally unsatisfactory
    2 - unsatisfactory
    1 - very unsatisfactory

20. Ease with which you connected life support hoses and performed "PRICE" check:
    6 - very satisfactory Comments:
    5 - satisfactory
    4 - marginally satisfactory
    3 - marginally unsatisfactory
    2 - unsatisfactory
    1 - very unsatisfactory

POST FLIGHT QUESTIONNAIRE | Card 14

21. Ability to assume proper ejection posture in non-high Gz environment:
    - 6 - very satisfactory Comments:
    - 5 - satisfactory
    - 4 - marginally satisfactory
    - 3 - marginally unsatisfactory
    - 2 - unsatisfactory
    - 1 - very unsatisfactory

22. Ability to "check six":
    - 6 - very satisfactory Comments:
    - 5 - satisfactory
    - 4 - marginally satisfactory
    - 3 - marginally unsatisfactory
    - 2 - unsatisfactory
    - 1 - very unsatisfactory

23. Overall mobility:
    - 6 - very satisfactory Comments:
    - 5 - satisfactory
    - 4 - marginally satisfactory
    - 3 - marginally unsatisfactory
    - 2 - unsatisfactory
    - 1 - very unsatisfactory

MOP 2.3 Interference

24. Anti-G suit interference with aircraft controls:
    - 6 - very satisfactory Comments:
    - 5 - satisfactory
    - 4 - marginally satisfactory
    - 3 - marginally unsatisfactory
    - 2 - unsatisfactory
    - 1 - very unsatisfactory

MOP 2.4 Verbal Communication

25. Ease of verbal communication under maximum G_z load:
    - 6 - very satisfactory Comments:
    - 5 - satisfactory
    - 4 - marginally satisfactory
    - 3 - marginally unsatisfactory
    - 2 - unsatisfactory
    - 1 - very unsatisfactory

POST FLIGHT QUESTIONNAIRE | Card 15

26. (LIBELLE only) Comparing LIBELLE to COMBAT EDGE, rate ease of verbal communication under maximum G_z load:
    - 5 - moderately better Comments:
    - 4 - barely better
    - 3 - the same
    - 2 - barely worse
    - 1 - moderately worse

MOP 2.5 Comfort

27. Overall comfort at 1 G_z:
    - 6 - very satisfactory Comments:
    - 5 - satisfactory
    - 4 - marginally satisfactory
    - 3 - marginally unsatisfactory
    - 2 - unsatisfactory
    - 1 - very unsatisfactory

28. Overall comfort at sustained high G_z:
    - 6 - very satisfactory Comments:
    - 5 - satisfactory
    - 4 - marginally satisfactory
    - 3 - marginally unsatisfactory
    - 2 - unsatisfactory
    - 1 - very unsatisfactory

29. Perceived level of sweating or heat stress at 1 G_z:
    - 6 - very satisfactory Comments:
    - 5 - satisfactory
    - 4 - marginally satisfactory
    - 3 - marginally unsatisfactory
    - 2 - unsatisfactory
    - 1 - very unsatisfactory

30. Perceived level of sweating or heat stress while performing sustained high G_z maneuvers:
    - 6 - very satisfactory Comments:
    - 5 - satisfactory
    - 4 - marginally satisfactory
    - 3 - marginally unsatisfactory
    - 2 - unsatisfactory
    - 1 - very unsatisfactory

POST FLIGHT QUESTIONNAIRE | Card 16

31. Check any problems you experienced during flight:
    _____ none Comments:
    _____ torso mobility restriction
    _____ itching or hot spots
    _____ binding, pinching, or pain
    _____ suit mechanical failure or damage

MOP 2.6 G estimation

32. Ability to fly at a desired G load "by the seat of your pants":
    6 - very satisfactory Comments:
    5 - satisfactory
    4 - marginally satisfactory
    3 - marginally unsatisfactory
    2 - unsatisfactory
    1 - very unsatisfactory

MOP 2.7 Aircrew Acceptance

33. Anti-G suit safety for operational use:
    6 - very satisfactory Comments:
    5 - satisfactory
    4 - marginally satisfactory
    3 - marginally unsatisfactory
    2 - unsatisfactory
    1 - very unsatisfactory

34. Overall opinion of anti-G suit worn:
    6 - very satisfactory Comments:
    5 - satisfactory
    4 - marginally satisfactory
    3 - marginally unsatisfactory
    2 - unsatisfactory
    1 - very unsatisfactory

POST FLIGHT QUESTIONNAIRE | Card 17

COMMENTS:

APPENDIX D Details of Statistical Analysis and Evaluations of Qualities of Comparers

ABSOLUTE v. RELATIVE questions and answers

There are six questions that *directly* ask the subject to compare the LIBELLE II with another G-suit. Answers to such questions are not an absolute comparison but a relative comparison. For most of these questions, the subjects rated the LIBELLE II "barely better" or "moderately better" than the baseline G-suit. Strictly statistically speaking, such results were labels and not numbers. Since these "labels" do not have a ratio property, they are not exactly usable as numbers. So any subsequent numerical manipulation such as establishing confidence intervals is somewhat theoretically flawed; however, this type of mathematics is widely practiced because:

1. It offers more descriptive results.
2. It is believed that some subjects develop a natural feel for an interval between two answers. So, in some sense, the responses are indeed "real" numbers and can be manipulated as numbers. In the same vein, the questionnaires are generally accepted in the human factors field, and have long been tuned to adjust the intervals of the answers; therefore, the reader might choose to accomplish subsequent arithmetic with results.

"Within-subjects" experimental design and comparisons

If a certain subject flew the COMBAT EDGE the day before flying the LIBELLE II, and rated the COMBAT EDGE "5. Satisfactory" and then rated the LIBELLE II "6. Very Satisfactory" the next day, it is reasonable to conclude that the subject considers the LIBELLE II superior to the COMBAT EDGE in this category (a relative comparison built on absolute comparisons).

Furthermore, the subject is particularly well qualified to make the comparison, partially because he flew the two suits in rapid succession. One can subtract the two ratings and conclude that this subject considers the LIBELLE II to be (6 minus 5 which equals) 1 rating category better than the COMBAT EDGE. Although in this case, the "1" would mean one category better, not a real number to be used in subsequent arithmetic operations; however, using the same argument as above, it is reasonable to treat these differences (often termed "ordinal") as a series of numbers in order to employ the "power" of the within subject experimental design.

In other words, the subject has deemed the LIBELLE II better than the COMBAT EDGE. If the subject's absolute ratings for LIBELLE II were just placed in a bin of other absolute ratings, then the power of

using the subject as a comparer would be lost. This type of analysis also assumes that no "asymmetrical training transfer" exists or that the COMBAT EDGE flight prepared the subject for the LIBELLE II flight just about as well as vice-versa. In fact, the subject is asked his fatigue level on a standard scale before and after every flight. Again, ignoring the problems of using labels as numbers, the differences in fatigue before and after the flight are a measure of the additional fatigue due to the flight itself. In similar fashion, the differences between these fatigue levels due to the G-suit are a measure of the differences between G-suits.

Master Comparers and Others

Some subjects were more highly qualified to make a side-by-side comparison based on recent and chronic experience with other G-suits, ideally under the same profile. In the last 6 months before this flight test:

Colonel Hank Morrow flew 24 sorties in COMBAT EDGE plus one high-G sortie after this test, which was used to fill out a survey for comparison (no COMBAT EDGE sorties exactly in this test).

Major Aaron George flew at least 30 times at high-G in COMBAT EDGE, numerous times in LIBELLE II, plus centrifuge training and approximately six flights during this test.

Major Kevin Prosser flew in COMBAT EDGE three to six times plus three times during this test.

Lt. Col. Sizoo flew in COMBAT EDGE a few times at high-G recently and once during this test.

APPENDIX E Consensus on some suitability value judgements

All those who flew the LIBELLE II (including master comparers) had a consensus on the ratings of the LIBELLE II in the categories in the table. Subjects were asked to rate the LIBELLE II by consensus on a "meatball chart." In each case, a true consensus was reached without arguments, "minority views," or persons with substantially different opinions on a question.

The ratings for the COMBAT EDGE were not from a consensus, but were the opinions of the Det 1 test team. They are included here for contrast.

Full green means exceptional; red means unsatisfactory. The meatballs on the chart for LIBELLE are a judgement call, which is a guess of what LIBELLE will be when mature (for example, will have pockets).

	Libelle	COMBAT EDGE	
$+G_z$ Protection	◎	◎	
Performance during $+G_z$	●	○	
Communication during $+G_z$	●	●	CE requires AGSM and PBG, Libelle strain does not use breath holding
Comfort during ground operations	○	◎	Problems exist even with comfort zippers unzipped
Comfort at $+1G_z$ in aircraft	○	◎	
Comfort during high-G	◎	◎	
Arm, foot, inguinal pain	●	◎	
Thermal stress	◎	○	
Mobility	○	◎	Marginal in air mostly with cross-cockpit reaching
Deployability/footprint	●	○	
Maintainability	●	○	
Reliability	●	○	Potential for exceptional because of lack of moving parts
Training life support techs	●	◎	Does not require positive pressure breathing
Training of maintainers	●	◎	No G valve or pressure breathing regulator to maintain
Training pilots	○	○	AGSM substantially different
Support/logistics	●	○	
Cost	●	◎	Big unknown, depends on old equipment saved
Don/doffing time	○	◎	
Flight equipment integration	●	◎	
NBC equipment integration	●	●	CE requires PBG, AERP is not PBG capable, Libelle works with AERP
Cockpit integration	●	◎	
Water survival	●	●	
Hanging harness	●	●	

●	**excellent**
◎	satisfactory
○	marginal
●	**unsatisfactory**

APPENDIX F Answers to Additional Questions

This project was a test of a prototype or a technology. A whole series of improvements and follow-on tests would have to ensue before the LIBELLE II would qualify as an operational, off-the-shelf G-suit; however, subjects were asked if they foresaw any problems in some areas (particularly “showstoppers”). Summaries of their responses and poignant responses are as follows:

How often in the past 6 months have you flown the COMBAT EDGE (or other G-suit) in a high-G environment? Please elaborate, particularly if other G-suits used.	
Colonel (Dr.) Bob Munsen	I have centrifuged twice with the COMBAT EDGE. No flying sorties in COMBAT EDGE.
Colonel Hank Morrow	24 sorties in CE
Colonel (Dr.) Peter Demitry	3 times—prior to that several times a month in F-15C.
Major (Dr.) Christian Ledet	CE about 2 months ago but less than 4G
Major Aaron George	At least 30 times at high G in CE and lots of times in LIBELLE II plus fuge
Major Kevin Prosser	In CE three to six times
Lieutenant Colonel Michael Sizoo	

How long ago was your last high-G flight in the COMBAT EDGE? If scheduled for COMBAT EDGE similar profile soon, please redo comparative questions after this second flight.	
Colonel (Dr.) Bob Munsen	Last high G flight with COMBAT EDGE was in 1993
Colonel Hank Morrow	3 weeks
Colonel (Dr.) Peter Demitry	About 4 months ago
Major (Dr.) Christian Ledet	No flight sooner than 18 months
Major Aaron George	Today, 2 Aug (after the last LIBELLE flight) (Basic Fighter Maneuvers)
Major Kevin Prosser	Last week about Jul 23
Lieutenant Colonel Michael Sizoo	Had a flight right after last F-16 ride otherwise, 1 CE and about 10 in CSU-13 B/P

Do you think that the LIBELLE offers any improvement over the CE in terms of combat capability or utility value-added? Please elaborate.	
Colonel (Dr.) Bob Munsen	To date (of course comparing centrifuge with flight, CE still provides me with better G-protection). Can sustain 9 Gs in CE in the centrifuge without full AGSM. However, I can sustain 8 G max with LIBELLE suit with full AGSM effort.
Colonel Hank Morrow	Yes, increased G capability. Yes, increased combat effectiveness. Big tactical advantage of being able to talk. There are problems with mobility in the cockpit, particularly reaching around cross cockpit is harder.
Colonel (Dr.) Peter Demitry	Yes, once in the air definitely better for G but still cumbersome.
Major (Dr.) Christian Ledet	I believe that Libelle will increase ability to sustain high Gs with less fatigue. This could translate into a greater sortie generation rate and force multiplier effect. With increased ops tempo permitting fighter to turn more frequently. The decreased fatigue levels were very important.
Major Aaron George	Can talk, think, and fight at 9 G for longer in LIBELLE than in EDGE. Suitability is "not as good" due to mobility restrictions.
Major Kevin Prosser	Personally, I see no noticeable increase in G-tolerance. Workload may decrease once new straining technique is perfected. However, restricted mobility and added weight do not justify the small (if any) improvement in performance.
Lieutenant Colonel Michael Sizoo	Yes, when functioning and used properly, ability to relax and talk at high Gs with less fatigue could be very significant. As long as operational/mobility integration acceptance issues are answered or covered.

Do you foresee problems with: Ordinary day-to-day "life" with the suit including possible increased alert status, TDY, arduous long low-G flights, etc. Focus also on comfort inside and outside of the cockpit, particularly on hot and cold days.	
Colonel (Dr.) Bob Munsen	No comment.
Colonel Hank Morrow	Yes, suit could be a little more comfortable.
Colonel (Dr.) Peter Demitry	Yes, problems with mobility but not thermal problems.
Major (Dr.) Christian Ledet	The suit is not a lounge around comfortable, thin, but it is quite comfortable in the cockpit. Progress in the elbow, knees, and basic layout is needed. However, the basic technology is good.
Major Aaron George	Thermal problems seems to be no issue. Mobility issues need to be addressed.
Major Kevin Prosser	Yes, heavier and less mobility makes the 12 hour wear difficult.
Lieutenant Colonel Michael Sizoo	Yes, improve comfort (only need front 'comfort' zippers).

Do you foresee problems with: Ejection, particularly assuming the position.	
Colonel (Dr.) Bob Munsen	No problem.
Colonel Hank Morrow	No problems.
Colonel (Dr.) Peter Demitry	No.
Major (Dr.) Christian Ledet	I suspect that there will be greater protection because of the materials that make up the suit and the greater surface area coverage.
Major Aaron George	No issue there.
Major Kevin Prosser	No, may affect the weight class of people who can use the seat (shift to 14 pounds lighter population).
Lieutenant Colonel Michael Sizoo	Some, but suit is getting more comfortable.

Do you foresee problems with: Probability or possibility of suit or parts of suit failing in flight.	
Colonel (Dr.) Bob Munsen	Similar failure rate as CSU-13 expected, however, improvements are needed. Specifically for this week, I had one zipper failure; this was the only material failure of consequence that we saw. Ripstop at zipper ends needs to be strengthened or these points will fail during donning because they are stressed. Knees will wear out easily because the material at the knees is not reinforced. My left knee spandex tore with kneeling the protective cover over the water channel snagged and tore. Lace lock on the back needs to be repositioned as it dug into back and is painful.
Colonel Hank Morrow	Yes, little pockets may tear.
Colonel (Dr.) Peter Demitry	No.
Major (Dr.) Christian Ledet	In flight failure would be very unlikely.
Major Aaron George	Some liquid leaks possible.
Major Kevin Prosser	No.
Lieutenant Colonel Michael Sizoo	Leaks?

Do you forsee problems with: Survival on land [after ejection including a parachute landing fall (PLF)]	
Colonel (Dr.) Bob Munsen	PLF will be affected as knees and hips will not flex easily. Water carried in the suit may be useful.
Colonel Hank Morrow	No significant problem, however, search and rescue [SAR] could present a real problem. Do you take the suit off or leave it on? If off, do you retain suit.
Colonel (Dr.) Peter Demitry	No.
Major (Dr.) Christian Ledet	Parachuting and PLF would be no problem. Escape and evasion in this suit is a negative, however, the water supply is a plus.
Major Aaron George	I think that the thick material provides extra protection for PLF and for getting dragged by chute. But potential mobility (running away problems may exist).
Major Kevin Prosser	Decreased mobility and increased weight will impede evasion.
Lieutenant Colonel Michael Sizoo	No (small).

Do you foresee problems with: Survival in water, particularly frigid water.	
Colonel (Dr.) Bob Munsen	Should not adversely affect water survival. However, suit mobility combined with immersion?
Colonel Hank Morrow	No significant problem, however, SAR could present a real problem. Do you take suit off or leave it on? If off, do you retain suit?
Colonel (Dr.) Peter Demitry	Needs to be addressed.
Major (Dr.) Christian Ledet	Currently not protective. However, with design changes, could be protective.
Major Aaron George	More coverage is more likely better protection.
Major Kevin Prosser	Yes, compatibility with poopy suit not demonstrated.
Lieutenant Colonel Michael Sizoo	No (small).

Do you foresee problems with: Compatibility with anti-exposure suit.	
Colonel (Dr.) Bob Munsen	Might cause mobility problem, but no integration issues expected.
Colonel Hank Morrow	Potentially very hard to move around in the cockpit.
Colonel (Dr.) Peter Demitry	Think that it needs to be engineered with the suit, not now.
Major (Dr.) Christian Ledet	I have not worn this.
Major Aaron George	I think that there will be some issues with heat stress in the anti-exposure suit.
Major Kevin Prosser	See above.
Lieutenant Colonel Michael Sizoo	Needs to be evaluated.

Do you foresee problems with: Compatibility with former Chemical/Biological/Radiological suit?	
Colonel (Dr.) Bob Munsen	Might cause mobility problem, but no integration issues expected.
Colonel Hank Morrow	Same as poopy suit.
Colonel (Dr.) Peter Demitry	Same as with anti-exposure suit.
Major (Dr.) Christian Ledet	I have not worn this.
Major Aaron George	Chemical/Biological/Radiological suit is not worthy of combat; needs redesign. Libelle has more coverage, and therefore possibly better protection.
Major Kevin Prosser	Yes.
Lieutenant Colonel Michael Sizoo	?

Do you foresee problems with: Day-to-day washing and wear and tear?	
Colonel (Dr.) Bob Munsen	Will probably need to be washed more frequently than the CSU-13 B/P because of sweating and wear next to skin.
Colonel Hank Morrow	Should not be a problem.
Colonel (Dr.) Peter Demitry	Inadequate [data?] at this point.
Major (Dr.) Christian Ledet	Currently there are some material integration issues such as elbow and knee elastic interface with the suit and zipper functions that are less than perfect. However, these can be fixed.
Major Aaron George	Good for wear and tear. Not sure about washing. It will be harder to wash than a flight suit, but no harder than CSU 13 B/P or COMBAT EDGE.
Major Kevin Prosser	No.
Lieutenant Colonel Michael Sizoo	No, but look at tube wear at joints, etc.

Do you foresee problems with: Inspection intervals and shelf life?	
Colonel (Dr.) Bob Munsen	Pre-flight inspection daily; 60-120 day inspection similar to CSU-13 B/P.
Colonel Hank Morrow	Same.
Colonel (Dr.) Peter Demitry	
Major (Dr.) Christian Ledet	Daily inspection/preflight.
Major Aaron George	Same inspections longer shelf life.
Major Kevin Prosser	No.
Lieutenant Colonel Michael Sizoo	No.

Do you foresee problems with: Storage and service life?	
Colonel (Dr.) Bob Munsen	Same as CSU-13 B/P.
Colonel Hank Morrow	
Colonel (Dr.) Peter Demitry	
Major (Dr.) Christian Ledet	Most components greater than one year.
Major Aaron George	Better, less moving parts.
Major Kevin Prosser	No.
Lieutenant Colonel Michael Sizoo	No (water in or out?)

Do you foresee problems with: Expected maintenance of suit ("life support" people) manpower and skill levels?	
Colonel (Dr.) Bob Munsen	Same as CSU-13 B/P.
Colonel Hank Morrow	Does water level need to be checked for every flight? If so, may need more people.
Colonel (Dr.) Peter Demitry	
Major (Dr.) Christian Ledet	Ability to sew and measure pressure.
Major Aaron George	Less skill needed for less complicated suit.
Major Kevin Prosser	No.
Lieutenant Colonel Michael Sizoo	No.

Do you foresee problems with: Deployability (portable/deployable including support equipment)?	
Colonel (Dr.) Bob Munsen	Repair similar to CSU-13.
Colonel Hank Morrow	Need the backpack.
Colonel (Dr.) Peter Demitry	Better than current systems.
Major (Dr.) Christian Ledet	Minimal equipment required.
Major Aaron George	Less support required.
Major Kevin Prosser	No.
Lieutenant Colonel Michael Sizoo	No.

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APPENDIX G Recommended Improvements

Obviously, any deficiency is the genesis of a recommended improvement; however, a couple of the subjects took the time to spell out the recommended improvements explicitly.

Recommended improvements

1. Increase knee/hip range of motion
2. Arms need to have more crossover arm reach. There seems to be binding as bicep/deltoid recruitment is used to reach across
3. Built-in fabric to allow increased range of motion when unloaded from Gs that becomes concentrically tight when loaded with plus Gs
4. Redesign crotch to allow increased mobility and decreased stick interference. Zipper should allow urination without opening the suit or altering harness
5. Pockets
6. Zippers with overruns on each end
7. Cleaner profile so that things do not get caught on equipment

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APPENDIX H Relative Costs

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ANTI-G SUIT COMPARISON ACTIVITY
OPERATING AND SUPPORT COST ESTIMATE
15 AUGUST 2000

The following represents logistics inputs for inclusion in an Operational and Support (O & S) cost estimate to compa
the current COMBAT EDGE (CE) ensemble to that of a 'Libelle' ensemble.

1.0 LIBELLE

1.1 PURPOSE

The purpose of this document is to provide a Rough Order of Magnitude O&S cost estimate for a 'Libelle' system.

1.2 SCOPE

This estimate looks at operational sustainment of a 'Libelle' suit ensemble.

1.3 ASSUMPTIONS

A. Initial procurement of 'Libelle' suit ensembles have been made. This addresses sustainment only.
NO costs are included for development, EMD or initial production activites. THERE IS CONSIDERABLE COST
No pressure breathing requirements exist, thus a simpler oxygen mask and regulator can be used.
It is further assumed 4,018 suits would have to be issued for a practical comparison to the CE system.

B. The composition and current prices of the Libelle suit ensemble are as follows

	Qty.	Price
MBU-12 /P Oxygen Mask	1	$220
HGU-55 /P Helmet (without Occipital Bladder)	1	$744
CRU-60 /P Integrated Terminal Block &/or PBG Chest Mounted Regu	1	$205
CWU-27/P Flt. Suit Coverall	2	$216
N/A Libelle Suit Assembly (ESTIMATED PRICE)	2	$5,400
Ensemble Total price:		$6,785

Support: XXX Anti-G Valve (capped - not reqd.)
Support: CRU-73 Oxygen Regulator

C. It is assumed each aircrew member will be issued two (2) flight suit coveralls and two(2) 'Libelle' suits.
The engineering estimate for a possible price of the 'Libelle' suit is $2,700 each. (FY00 dollars)

D. Maintenance. 95% of the time maintenance will be performed by personnel in the E3 to E5, 3 to 5 skill level
range. Approximately 5% of the time maintenance may be performed by individuals (E6 to E7) with a skill level
There is no requirement for depot level maintenance support. Preflight and postflight inspections by specialists
included. This reflects current maintenance practices for the existing Anti-G suit.

E. Use of ATAGS Reliability and Maintainability Assessment by Mitre determined repairs. 100% of component repl
and sewing will be accomplished by Survival Equipment Specialists, grades E3 to E7, skill levels of 3 to 7.
The 'Libelle' system is assumed to be similar.

F. ATAGS Reliability and Maintainability Assessment by Mitre determined the Mean Time Between Failure (MTBF
be approximately 600 flight hours. This assumption is also used for the 'Libelle' system.

G. The Mean Time To Repair (MTTR) Anti-G garments is 0.5 hours or less, at 80 % confidence or more. MTTR is
defined as the total repair time excluding waiting time for resupply of parts and tools by the number of repair ins

H. Periodic Inspections and Testing. Intervals for these maintenance requirements remain the same as the current
fielded CSU-13B/P Anti-G garment. They are performed monthly, and are generally completed within thirty (30)
minutes. This is also assumed for the 'Libelle' system.

I. Infrequently used Anti-G garments will be inspected / pressure tested prior to being placed in storage and prior
next use. Maximum time between inspection will not exceed six (6) months. These maintenance requirements a
generally completed within 30 minutes.

J. Anti-G garments do not require any special packaging, support equipment or facilities. If folded, the 'Libelle' blac
would need to be removed or stored slightly differently (unfolded) with the bladders installed.

K. Operational and Maintenance Training Concept. On-Job-Training (OJT) is the primary method of training person
to maintain Anti-G garments. Introductory and familiarization training for new personnel will be conducted at form
technical training schools. It is assumed 'Libelle' instruction would include eight hours formal training and two we

L. Defects in Anti-G garments currently fielded are managed through the Product Quality Deficiency Report (PQDR
process. No change is contemplated.

M. Data received from a few squadrons reflect new ensembles being acquired annually as pilots (nav.,etc.) new to CE-type units PCS in. An assumption made within this model uses the helmet bladder consumption quantity as t overall new ensemble quantity. This same quantity is used for the 'Libelle' quantity as well.

The comparison team consists of:

Name	Organization	Responsibilities	Phone #
Capt. Va'shon Moore	311-HSW/YACL	ATAGS Program Manager	4-4896
Charles Flick	311-HSW/YACLM(SAIC	Sr. Systems Engineer	4-4154
Bud Glass	311-HSW/YACLM(SAIC	Senior Analyst	4-3935
Alfonso Gonzalez	311-HSW/YAR(Core 6 S	Senior Analyst	4-6897
John Hopkins	311-HSW/YACL	Logistics Manager	4-4897
John Reedy	311-HSW/YACLE(SAIC)	Senior Analyst	4-4545

1.4 OSD INFLATION INDICES

OSD Inflation Indices issued 06 Jan 2000 for base year FY00 are used:

	2000	2001	2002	2003	2004	2005	2006
3400 Op & Mtn.	1.000	1.015	1.030	1.046	1.067	1.088	1.110
3400 O&M Weighted	1.008	1.023	1.039	1.057	1.078	1.100	1.122
3500 'Total'	1.000	1.039	1.077	1.112	1.147	1.184	1.221

1.5 COST ESTIMATE SUMMARY

Appropriation	**BY$**	**TY$**
3400	**16,817,232**	**17,991,636**
3500	**11,126,099**	**12,572,492**
Total	**27,943,332**	**30,564,128**

Appropriation BY$	FY01	FY02	FY03	FY04	FY05	FY06	TOTAL
3400	2,802,872	2,802,872	2,802,872	2,802,872	2,802,872	2,802,872	########
3500	1,854,350	1,854,350	1,854,350	1,854,350	1,854,350	1,854,350	########
Total	4,657,222	4,657,222	4,657,222	4,657,222	4,657,222	4,657,222	########

Appropriation TY$	FY01	FY02	FY03	FY04	FY05	FY06	TOTAL
3400	2,867,338	2,912,184	2,962,636	3,021,496	3,083,159	3,144,822	########
3500	1,926,670	1,997,135	2,062,037	2,126,939	2,195,550	2,264,161	########
Total	4,794,008	4,909,319	5,024,673	5,148,435	5,278,710	5,408,984	########

SUMMARY:	**TOTALS:**	
Description:	**BY$**	**TY$**
2.1.2.1 INITIAL INSTALLATION:		
A.1 AIRCREW LIFE SUPT / SURVIVAL EQ. SPECIALISTS ON-THE-JOB TRAIN.	1,156,865	1,307,257
A.2 FORMAL SPECIALISTS TRAINING	552,634	624,476
2.1.2.2 INSPECTIONS AND TESTING:	9,164,642	########
2.1.2.3 UNSCHEDULED MAINTENANCE:		
2.1.2.3.1 LABOR	224,858	254,089
2.2 UNIT LEVEL CONSUMPTION:	########	########
2.2.2 CONSUMABLE MATERIAL / REPAIR PARTS	112,864	120,746
2.8.4 SUSTAINMENT SUPPORT:		
2.8.4.2 LOGISTICS SUPPORT:	21,762	$23,282
2.8.4.2.1 INVENTORY MANAGEMENT	27,101	30,625
2.8.4.2.2 TECHNICAL MANAGEMENT	11,606	$12,417
Summary:	########	########

2.0 OPERATING AND SUPPORT COST ELEMENTS

2.1 MISSION PERSONNEL

No increase in manpower to maintain and/or support is envisioned.
On-the-job training (OJT) is the primary means of preparing personnel to maintain 'Libelle' equipment ensembles. In addition to training at the unit, support personnel will receive introductory and familiarization at the respective formal technical training school. Maintenance support will be shared between Aircrew Life Support Specialists, Air Force Specialty Code (AFSC) 1T1XO and Survival Equipment Specialists, (AFSC) 2T7X4. The commonality between the existing and contemplated Anti-G garments allows use of the same support equipment.

2.1.1 OPERATIONS Not applicable.

2.1.2 MAINTENANCE

The following grid reflects the composite hourly pay rate of military personnel who support and maintain Combat Ed
average of grades is used for costing purposes. This average is 95% of (E3+E4+E5)/3 + 05% of (E6+E7)/2 or $ 17.
This 'average' represents general maint./repair activities. Rates are from AFI 65-503, table A20-2.

GRADE	FY00		FY00 values:
E3	$13.49	maintenance rate(aver	$17.46
E4	$17.22		
E5	$20.44	training rate used (E-7	$27.14
E6	$23.55		
E7	$27.14	repair rate used (aver.	$17.46

2.1.2.1 INITIAL LIFE SUPPORT TRAINING

A.1 FISCAL YEAR SPREAD (ON-THE-JOB AIRCREW LIFE SUPPORT / SURVIVAL EQUIPMENT SPECIALISTS

Appropriation 3500	FY01	FY02	FY03	FY04	FY05	FY06	TOTAL
BY$	192,811	192,811	192,811	192,811	192,811	192,811	1,156,865
TY$	200,330	207,657	214,406	221,154	228,288	235,422	1,307,257

A.2 FISCAL YEAR SPREAD (FORMAL SPECIALISTS TRAINING)

Appropriation 3500	FY01	FY02	FY03	FY04	FY05	FY06	TOTAL
BY$	92,106	92,106	92,106	92,106	92,106	92,106	552,634
TY$	95,698	99,198	102,421	105,645	109,053	112,461	624,476

B. COST ELEMENT CONTENTS

Training requirements are assumed to differ between COMBAT EDGE (CE) and Libelle. With CE there is an empha
on the pressure breathing aspect that would not be present with Libelle. Turnover, then, implies there will be a diffe
implication for the two systems.
This cost element addresses man-power requirements necessary to train specialists new to Libelle suit ensembles.

C. SUMMARY OF ESTIMATING AND FISCAL YEAR SPREAD PROCEDURES

The team estimates the Libelle systems at each operational unit will be supported by two (2) personnel (E-3's to E-
within each squadron. As training experience indicates approximately two support specialists weekly are being repla
CE support, this estimate will use the same activity for new personnel provided formal technical training for the 'Libe
In addition to the formal training, there is also On-the-Job Training (OJT) that occurs providing the 'hands-on' experi

D. DETAILED BASIS OF THE ESTIMATE

Training includes sizing, fitting and adjustments required for the aircrew members along with inspection and testing
procedures. It also includes the procedures for maintenance as well as what can be repaired and how each
repairable item is to be repaired. It is assumed the specialists are a composite of E-3's, E-4's and E-5's, while the
instructor is assumed an E-7.
At this time, the information on hand indicates there are 98 squadrons fielding F-15 and -16 aircraft (59 active duty;
For this estimate, it's assumed some specialists from the ANG and Reserves are replaced annually due to retireme
an assumption the specialists in the Active Duty squadrons either PCS to a non-C.E. unit or leave the service at the
enlistment. The result of these assumptions is a turn-over in personnel at the rate of 138 annually. The training sch
Sheppard AFB' best estimate is two per class (one class weekly and addit. class every third week) eventually supp
This same scenario is estimated for the 'Libelle' system.
The formal training cost estimates one instructor (E-7) teaching eight (8) hours and the specialists being trained pe
The primary difference in this area relates to the pressure breathing aspect present in CE, but not assumed with 'Li
These classes, per Sheppard AFB, TX, Life Support Training School, are conducted weekly with an average of eigh
students per class. In addition, every third week an additional eight (8) students are taught during an alternate class
The calculation is: instructor's hrly. rate X 8 hrs./wk. X (52+17) classes/yr. plus specialists hrly. rate X no. students
(8X52)+(8X17)=552 students
The on-the-job training assumes the specialists are mentored by a peer. The team estimates 10 days to be directed
This model assumes the 80 hours per trainee including the mentors time; anti-g suit not exclusively the only activity
The calculation is: specialists hourly rate X no. of students X 80 hours.

Formal training time: (annually)	$92,106
OJT Training time: (annually)	$192,811

2.1.2.2 INSPECTIONS AND TESTING

Recurring periodic inspections and pressure testing are conducted monthly. Inspection and pressure testing requirements for infrequently used CE garments will not exceed six (6) months. Preflight and Post flight inspections are performed before/after each use. Under normal operational conditions each Libelle suit is estimated to receive annually twelve inspections and pressure tests.

A. FISCAL YEAR SPREAD

Appropriation 3500	FY01	FY02	FY03	FY04	FY05	FY06	TOTAL
BY$	1,527,440	1,527,440	1,527,440	1,527,440	1,527,440	1,527,440	9,164,642
TY$	1,587,010	1,645,053	1,698,514	1,751,974	1,808,489	1,865,005	########

B. COST ELEMENT CONTENTS

This element covers cost the user will incur performing periodic preventive maintenance and general upkeep on Lib

C. SUMMARY OF ESTIMATING AND FISCAL YEAR SPREAD PROCEDURES

The estimated time for accomplishing periodic inspections and pressure testing is 0.5 hours. Post flight inspections are visual inspections performed after use, and can generally be performed within five (5) minutes. These inspectio tests are performed by Life Support Specialists whose averaged hourly rates are defined in section 2.1.2 and depict in the chart below. Preflight inspections are estimated by the comparison team to take five (5) minutes to accomplis

D. DETAILED BASIS OF THE ESTIMATE

Inspections and testing costs will occur at regular intervals throughout the life cycle of each Libelle ensemble. The comparison team was provided an estimated no. of sorties annually by ACC and average duration per flight. The number of flights provided was one hundred forty (140) and flight hours at two hundred fifty-two (252).

The inspection time is estimated as follows: (10 min. for the oxygen connector replacing the ITB as used in the CE configuration; 30 min. for mask assembly; 10.5 min. suit ensemble)/60.

Calculations: The estimated inspection time X 12 (once monthly) X hrly. wage X no. of suits yields insp./test cos The pre and post calculation is similar: est. time X no. flts. annually X hrly. rate X no. suits yields flt. Insp. activity.

Type of inspection	% of 1 hour	Occurrence	Total Time/ Suit (Hrs)
Inspection and Test	84.17%	12 times per year	10.10
Pre Flight	8.33%	140 flts. Annually	11.67
Post Flight	8.33%	140 flts. Annually	11.67
		Total hours per year per suit:	33.43

Base Year Dollars (BY$):

Trained Life Supt.Spe	Hrly.Wage	Total Time Per Suit	Total No. of Suits	Cost / year:
Avg E3-E7 Grade - ins	$17.46	10.10	4018	$708,751
Avg E3-E7 Grade - Pr	$17.46	11.67	2009	$409,345
Avg E3-E7 Grade - Po	$17.46	11.67	2009	$409,345

2.1.2.3 UNSCHEDULED MAINTENANCE

Unscheduled maintenance is defined as corrective maintenance required by item condition. For this estimate, unscheduled maintenance is relative to sewing operations, component removal/replacement and record keeping.

2.1.2.3.1 LABOR

Based on requirements outlined in the Critical Item Development Specification (CIDS) for ATAGS and the result of t ATAGS Reliability and Maintainability Assessment by Mitre, the Mean Time To Repair (MTTR) is assumed to be 0.5 hours or less. It is important to note component replacement is assumed limited to the slide fastener on the waist pa legs and pockets, the dot snap fasteners, slide fastener stops, 'Libelle' bladders and lacing cords.
Additionally, the specialists also maintain computer records of inspections made and items replaced.

An additional labor element is included for the removal, replacement and testing of replaced oxygen regulators. The labor rate used is $17.46 per hour.

A. FISCAL YEAR SPREAD

Appropriation 3500	FY01	FY02	FY03	FY04	FY05	FY06	TOTAL
BY$	37,476	37,476	37,476	37,476	37,476	37,476	224,858
TY$	38,938	40,362	41,674	42,985	44,372	45,759	254,089

B. COST ELEMENT CONTENTS

This cost element covers the cost of labor the user will incur performing unscheduled maintenance, repairs and component removal / replacement for the Libelle ensemble.

C. SUMMARY OF ESTIMATING AND FISCAL YEAR SPREAD PROCEDURES

The estimated time to accomplish sewing and component removal / replacement maintenance operations and the estimated percentage of maintenance requirements are per the Mitre analysis.

D. DETAIL BASIS OF THE ESTIMATE

Labor hours are estimated at 0.5 hours (time to accomplish unscheduled maintenance task on one Anti-G garment)
Labor rates are based on the per hour composite salary of E3 - E7 rates defined in section 2.1.2 as $17.46 / hr.
Assume data entry actions to a computer based maintenance record system will be three (3) minutes per repair.
Air Combat Command estimates each pilot will fly 252 hours per year.
For this estimate, the requirements document data that indicates MTBF for each component is used to determine the majority of anticipated failures. In addition, one can assume some abuse and accidental damage will occur. An additional ten percent is added to the this data to account for these conditions. This information, along with average pilots flight hours annually and the number of Libelle ensembles in use (same value as CE) provide an estimated overall number of failures annually.
An example calculation is: 252 flt.hrs/yr X no.suits(2009) divided by MTBF (5,725hrs) equals 88+ failures for ITBs.

Item:	MTBF hrs:	Flt. Hrs:	CE suits	theoretical Failures/yr.	additional 10 percent:	Failures used:
ITB replcmnt: O2 con	5,725	252	2009	88.43	8.84	97
Mask	2,348	252	2009	215.62	21.56	237
Helmet Modif. Kit (N/	6,599	252	0	0	0	0
Libelle suit **	635	126	4018	797.27	199.32	997
			Total:	1101.32		1331

** This estimated MTBF is clculated as the sum of the inverse relationships for the CE vest and 13B/P pant times 1 and rounded. The comparison team assumes the 'Libelle' suit MTBF at 1.25 times that of the CE vest and 13B/P pa

Current consumption per data acquired by equip. specialists DLA- Phil. & DLA-Colum. indicate annual consumption for the CE ensemble appears to be approximately 215 ensembles annually. Assuming the 215 ensembles are new, items repaired equal 1,331 - 215 or 1,116. This is 1116/1331 or 83.8% of the total.

An additional labor element is included for the removal, replacement and testing of replaced oxygen regulators. The labor rate used is $17.46 per hour. The estimated removal, replacement and testing of an oxygen regulator is 2.0 hours maximum per Environmental group. This also allows for bent clips and damaged fastening components The calculation is: no. of regulators X no. of hours involved X hourly rate.

Fiscal Year:		FY01	FY02	FY03	FY04	FY05	FY06	TOTAL:
Cost / Hr.	$17.46							
MTTR $ D.	0.55							
Incr. annually		83.8%	83.8%	83.8%	83.8%	83.8%	83.8%	
Total Failu	1,331							
No.Repairs/Year		1,116	1,116	1,116	1,116	1,116	1,116	
Total Cost: (Base Yea		10,720	10,720	10,720	10,720	10,720	10,720	64,322
Regulator replacemer		26,756	26,756	26,756	26,756	26,756	26,756	160,536

2.1.2.3.2 LABOR (WARRANTY REPLACEMENT)
Defects in Anti-G garments currently fielded are managed through the Product Quality Deficiency Report (PQDR) process. Thus it is assumed Libelle anti-g garments would be managed in the same manner.

2.2 UNIT LEVEL CONSUMPTION
Includes the cost of support materials consumed at the unit level.

A. FISCAL YEAR SPREAD

Appropriation 3400	FY01	FY02	FY03	FY04	FY05	FY06	TOTAL
BY$	2,778,500	2,778,500	2,778,500	2,778,500	2,778,500	2,778,500	########
TY$	2,842,406	2,886,862	2,936,875	2,995,223	3,056,350	3,117,477	########

B. COST ELEMENT CONTENTS
This element addresses the annual consumption of equipment that comprise the Libelle ensemble.

C. SUMMARY OF ESTIMATING AND FISCAL YEAR SPREAD PROCEDURES
From data inquiries received from the POC's for CE equipment items, the following is an estimated amount of mate replaced on an annual basis, Air Force wide, to support the Libelle system. This model doesn't address repair of air

D. DETAIL BASIS OF THE ESTIMATE
The following information has been received pertaining to item consumption. The premise here is that some items c longer be repaired and are hence replaced. The engineering estimate is based upon experience within the team.
Pilot turnover is the basis for costing complete ensembles. The quantity used for complete ensembles assumes hel bladder modif. kits acquired will be for pilots new to CE units. This quantity estimated for the Libelle system is the sa 'ensemble' quantity as that used for the CE comparison.
The consumption data received includes the following:

Item:	Comment:	Annual Consumption:	Cost / Item	Annual Cost:
Integ.Term.Blk.; O2 c	compl.assy.	261	205	$53,505
Oxygen Mask	4 sizes	49	220	$10,780
Flt. Suit Coverall	2 author.; 1 repl annually	1794	108	$193,752
G' Hoses	not required	0	83	$0
Regulators	CRU-73/P	744	1427	########
Anti-G Valve	not required	0	1036	$0
Anti-G Valve	not required	0	1356	$0
Complete Ensemble	estimated Libelle value	215	6785	########
			Total -->	########

2.2.1 POL/ENERGY CONSUMPTION Not applicable.

2.2.2 CONSUMABLE MATERIAL / REPAIR PARTS

A. FISCAL YEAR SPREAD

Appropriation 3400	FY01	FY02	FY03	FY04	FY05	FY06	TOTAL
BY$	18,811	18,811	18,811	18,811	18,811	18,811	112,864
TY$	19,243	19,544	19,883	20,278	20,692	21,106	120,746

B. COST ELEMENT CONTENTS

This element covers estimated costs of materials repaired in the operation, maintenance and support of Libelle ens
only parts anticipated to require repair are the slide fasteners (waist, legs, chest and pockets), snap fasteners and l
Note: the bladders are tubular and the vendor indicates they are not repairable - they must be replaced.

C. SUMMARY OF ESTIMATING AND FISCAL YEAR SPREAD PROCEDURES

Each Libelle garment contains the following estimated replaceable hardware.

D. DETAILED BASIS OF ESTIMATE

This estimate reflects average case component replacement.

ITEM	QTY.	COST ea.	Cost/Suit		
Libelle System:					
thigh zipper	6	$7	$42.00		
calf zipper	6	$7	$42.00		
arm zipper	2	$5	$10.00		
chest zipper	1	$8	$8.00		
waist zipper	1	$7	$7.00		
pocket zipper	2	$5	$10.00		
lacing cord	10	$2	$20.00		
snap fastener	8	$2	$16.00		
bladders (cost estima	4	$150	$600.00	average =	$18.88

The average item cost per garment in FY00 dc Libelle sys. $18.88
Per the comparison team, estimate one such item per repair as there will be repairs made requiring no parts and otl
The calculation is the No. of Suits X the Matl. per Suit Cost.

Fiscal Year:	FY01	FY02	FY03	FY04	FY05	FY06	TOTAL
# of Suits *	997	997	997	997	997	997	
Matl. / Suit	$18.88	$18.88	$18.88	$18.88	$18.88	$18.88	
Total cost / Year:	$18,811	$18,811	$18,811	$18,811	$18,811	$18,811	$112,864

* No. of suits based on percent of suits repaired during unscheduled maintenance (ref. 2.1.2.3.1 - Labor)

2.3 DEPOT LEVEL REPAIRABLES Not applicable.

2.4 TRAINING MUNITIONS / EXPENDABLE STORES Not applicable.

2.5 INTERMEDIATE MAINTENANCE (EXTERNAL TO UNIT) Not applicable.

2.6 DEPOT MAINTENANCE Not applicable.

2.7 CONTRACTOR SUPPORT Not applicable.

2.8 SUSTAINING SUPPORT

2.8.1 SUPPORT EQUIPMENT REPLACEMENT
Anti-G suit ensembles are supported using test equipment and attaching cords, tubes, etc.

2.8.2 MODIFICATION KIT PROCUREMENT/INSTALLATION (AFTER PRODUCTION/DEPLOYMENT)
Not applicable.

2.8.3 OTHER RECURRING INVESTMENT Not applicable.

2.8.4 SUSTAINMENT SUPPORT

2.8.4.1 SURVEILLANCE TESTING
It is assumed by the comparison team surveillance testing will not be conducted.

2.8.4.2 LOGISTICS SUPPORT
Logistics support from the sustaining activity, HSW/YACL, is assumed moderate. This support of CE is estimated by the comparison team to require approximately seventy-five (75) hours annually of a GS-11 salary grade - level five (5) to provide adequate logistical support needed for this system. The FY00 composite hourly salary rate for a GS-11, level 5, is $48.36. Rate source: AFI 65-503, tab

Appropriation 3400 Logistics Support (BY):

Fiscal Year:	FY01	FY02	FY03	FY04	FY05	FY06	TOTAL
# of Hours	75	75	75	75	75	75	
Logis. Rate	$48.36	$48.36	$48.36	$48.36	$48.36	$48.36	
Total cost / Year: (BY	$3,627	$3,627	$3,627	$3,627	$3,627	$3,627	$21,762
Total cost / Year: (TY	$3,710	$3,768	$3,834	$3,910	$3,990	$4,069	$23,282

2.8.4.2.1 INVENTORY MANAGEMENT
This element is based on initial item issuance to aircrew member requiring ensemble - a one-time activity. Assigned as a form "538 record", there will be no ongoing inventory management activity per se. There is assumed an initial cost of approximately 12 minutes of an E-6 time ($22.86/hr.) to complete the 538 form as the ensemble is first issue
A total of 215 initial personal gear forms are estimated to be completed and filed annually.
In addition to personal gear, there is also the replacement of CRU-73/P oxygen regulators. The usage rate currently averaging twenty-two (22) units quarterly. An assumption used is the 'same' rate of replacement for the two types of regulator supporting CE is required. This would total 744 annually and be recorded on aircraft maintenance records The same time estimate is applied to the aircraft maintenance record.
The calculation for these transactions are the hourly rate X overall recording time / activity X quantities involved.

Appro.3500 Inventory	FY01	FY02	FY03	FY04	FY05	FY06	TOTAL
Total (BY)	$4,517	$4,517	$4,517	$4,517	$4,517	$4,517	$27,101
Total (TY)	$4,693	$4,865	$5,023	$5,181	$5,348	$5,515	$30,625

2.8.4.2.2 TECHNICAL MANAGEMENT
Anti-G suit ensembles are a daily use item requiring periodic inspections, testing and repairs. Therefore, technical data exists to support the system. Instructions reflected in the technical data are sufficient to maintain the system. Technical order maintenance for the Libelle system is estimated by the comparison team to require forty (40) hours by a grade level GS-11 annually. This activity will maintain T.O.'s current for changes that may occur with suit design as well as changes with procedures and policies.
The FY00 composite hourly salary rate for a GS-11, level 5, is $48.36.

Appro.3400 Tech.Order Maint.(BY):

Fiscal Year:	FY01	FY02	FY03	FY04	FY05	FY06	TOTAL
# of Hours	40	40	40	40	40	40	
T.O.mtn.rate	$48.36	$48.36	$48.36	$48.36	$48.36	$48.36	
Total cost / Year: (BY	$1,934	$1,934	$1,934	$1,934	$1,934	$1,934	$11,606
Total cost / Year: (TY	$1,979	$2,010	$2,045	$2,085	$2,128	$2,170	$12,417

2.8.4.3 SOFTWARE MAINTENANCE SUPPORT Not applicable.

2.8.4.4 SIMULATOR OPERATIONS Not applicable.

2.9 INDIRECT SUPPORT Not applicable.

ANTI-G SUIT COMPARISON ACTIVITY
OPERATING AND SUPPORT COST ESTIMATE
15 AUGUST 2000

The following represents logistics inputs for inclusion in an Operational and Support (O & S) cost estimate to compa
the current COMBAT EDGE ensemble to that of a 'Libelle' ensemble.

3.0 COMBAT EDGE

3.1 PURPOSE

The purpose of this document is to provide a Rough Order of Magnitude O&S cost estimate for COMBAT EDGE sy

3.2 SCOPE

This estimate looks at operational sustainment of a COMBAT EDGE suit ensemble.

3.3 ASSUMPTIONS

A. Initial procurement of COMBAT EDGE suit ensembles have been made (best information is 2,009 suits are in us

B. The composition and current prices of the COMBAT EDGE suit ensemble are

	Qty.	Price
MBU-20 /P Oxygen Mask	1	$1,040
CSU-17 /P Vest Assembly	1	$394
HGU-55 /P Helmet with Occipital Bladder (KMU-511/P)	1	$924
CRU-94 /P Integrated Terminal Block &/or PBG Chest Mounted Regu	1	$320
CSU-13 B/P Lower Anti-G Pant Garment	2	$1,150
CWU-27/P Flt. Suit Coverall	3	$324
Ensemble Total price:		$4,152

Support: TTU-529/E Pressure Breathing Oxygen Flight Ensemble T = $14K to buy - not had to replace any to date have had some repairable items replaced.

Support: XXX Anti-G Valve

Support: CRU-73, CRU-93 & CRU-98 Oxygen Regulators

C. Based on current CSU-13B/P operational procedures, it is assumed each aircrew member will be issued two (2) Anti-G pants. One (1) upper COMBAT EDGE vest is issued. Three (3) flight suits are authorized.

D. Maintenance. 95% of the time maintenance will be performed by personnel in the E3 to E5, 3 to 5 skill level range. Approximately 5% of the time maintenance may be performed by individuals (E6 to E7) with a skill level There is no requirement for depot level maintenance support. Preflight and postflight inspections by specialists included. This reflects current maintenance practices for the existing Anti-G suit.

E. Use of ATAGS Reliability and Maintainability Assessment by Mitre determined repairs. 100% of component repl and sewing will be accomplished by Survival Equipment Specialists, grades E3 to E7, skill levels of 3 to 7. COM EDGE is assumed to be similar.

F. ATAGS Reliability and Maintainability Assessment by Mitre determined the Mean Time Between Failure (MTBF be approximately 600 flight hours. This assumption is also used for COMBAT EDGE.

G. The Mean Time To Repair (MTTR) Anti-G garments is 0.5 hours or less, at 80 % confidence or more. MTTR is defined as the total repair time excluding waiting time for resupply of parts and tools by the number of repair ins

H. Periodic Inspections and Pressure Testing. Intervals for these maintenance requirements remain the same as th as the currently fielded CSU-13B/P Anti-G garment. They are performed monthly, and are generally completed within thirty (30) minutes.

I. Infrequently used Anti-G garments will be inspected / pressure tested prior to being placed in storage and prior next use. Maximum time between inspection will not exceed six (6) months. These maintenance requirements a generally completed within 30 minutes.

J. Anti-G garments do not require any special packaging, support equipment or facilities.

K. Operational and Maintenance Training Concept. On-Job-Training (OJT) is the primary method of training person to maintain Anti-G garments. Introductory and familiarization training for new personnel will be conducted at formal technical training schools. COMBAT EDGE instruction includes thirty hours formal training and one mont

L. Defects in Anti-G garments currently fielded are managed through the Product Quality Deficiency Report (PQDR process. No change is contemplated.

M. Data received from a few squadrons reflect new ensembles being acquired annually as pilots (nav.,etc.) new to CE units PCS in. An assumption made within this model uses the helmet bladder consumption quantity as this overall new ensemble quantity. This same quantity value is used for the Libelle value as well.

The comparison team consists of:

Name	Organization	Responsibilities	Phone #
Capt. Va'shon Moore	311-HSW/YACL	ATAGS Program Manager	4-4896
Charles Flick	311-HSW/YACLM(SAIC	Sr. Systems Engineer	4-4154
Bud Glass	311-HSW/YACLM(SAIC	Senior Analyst	4-3935
Alfonso Gonzalez	311-HSW/YAR(Core 6 S	Senior Analyst	4-6897
John Hopkins	311-HSW/YACL	Logistics Manager	4-4897
John Reedy	311-HSW/YACLE(SAIC)	Senior Analyst	4-4545

3.4 OSD INFLATION INDICES

OSD Inflation Indices issued 06 Jan 2000 for base year FY00 are used:

	2000	2001	2002	2003	2004	2005	2006
3400 Op & Mtn.	1.000	1.015	1.030	1.046	1.067	1.088	1.110
3400 O&M Weighted	1.008	1.023	1.039	1.057	1.078	1.100	1.122
3500 'Total'	1.000	1.039	1.077	1.112	1.147	1.184	1.221

3.5 COST ESTIMATE SUMMARY

Appropriation	**BY$**	**TY$**
3400	**42,104,340**	**45,044,626**
3500	**15,979,817**	**18,057,193**
Total	**58,084,157**	**63,101,819**

Appropriation BY$	FY01	FY02	FY03	FY04	FY05	FY06	TOTAL
3400	7,017,390	7,017,390	7,017,390	7,017,390	7,017,390	7,017,390	########
3500	2,663,303	2,663,303	2,663,303	2,663,303	2,663,303	2,663,303	########
Total	9,680,693	9,680,693	9,680,693	9,680,693	9,680,693	9,680,693	########

Appropriation TY$	FY01	FY02	FY03	FY04	FY05	FY06	TOTAL
3400	7,178,790	7,291,068	7,417,381	7,564,746	7,719,129	7,873,512	########
3500	2,767,172	2,868,377	2,961,593	3,054,808	3,153,351	3,251,893	########
Total	9,945,962	10,159,445	########	########	########	########	########

SUMMARY:	**TOTALS:**	
Description:	**BY$**	**TY$**
2.1.2.1 INITIAL INSTALLATION:		
A.1 AIRCREW LIFE SUPT / SURVIVAL EQ. SPECIALISTS ON-THE-JOB TRAIN.	2,487,260	2,810,604
A.2 FORMAL SPECIALISTS TRAINING	2,072,376	2,341,785
2.1.2.2 INSPECTIONS AND TESTING:	########	########
2.1.2.3 UNSCHEDULED MAINTENANCE:		
2.1.2.3.1 LABOR	235,514	266,131
2.2 UNIT LEVEL CONSUMPTION:	########	########
2.2.2 CONSUMABLE MATERIAL / REPAIR PARTS	281,270	300,912
2.8.4 SUSTAINMENT SUPPORT:		
2.8.4.2 LOGISTICS SUPPORT:	36,270	$38,803
2.8.4.2.1 INVENTORY MANAGEMENT	27,101	30,625
2.8.4.2.2 TECHNICAL MANAGEMENT	21,762	$23,282
Summary:	########	########

4.0 OPERATING AND SUPPORT COST ELEMENTS

4.1 MISSION PERSONNEL

No increase in manpower to maintain and/or support is envisioned.
On-the-job training (OJT) is the primary means of preparing personnel to maintain Combat Edge ensembles. In addition to training at the unit, support personnel will receive introductory and familiarization at the respective formal technical training school. Maintenance support will be shared between Aircrew Life Support Specialists, Air Force Specialty Code (AFSC) 1T1XO and Survival Equipment Specialists, (AFSC) 2T7X4. The commonality between the existing and contemplated Anti-G garments allows use of the same support equipment.

4.1.1 OPERATIONS Not applicable.

4.1.2 MAINTENANCE

The following grid reflects the composite hourly pay rate of military personnel who support and maintain Combat Ed
average of grades is used for costing purposes. This average is 95% of (E3+E4+E5)/3 + 05% of (E6+E7)/2 or $ 17.
This 'average' represents general maint./repair activities. Rates are from AFI 65-503, table A20-2.

GRADE	FY00		FY00 values:
E3	$13.49	maintenance rate(aver	$17.46
E4	$17.22		
E5	$20.44	training rate used (E-7	$27.14
E6	$23.55		
E7	$27.14	repair rate used (aver.	$17.46

4.1.2.1 INITIAL LIFE SUPPORT TRAINING

A.1 FISCAL YEAR SPREAD (ON-THE-JOB AIRCREW LIFE SUPPORT / SURVIVAL EQUIPMENT SPECIALISTS

Appropriation 3500	FY01	FY02	FY03	FY04	FY05	FY06	TOTAL
BY$	414,543	414,543	414,543	414,543	414,543	414,543	2,487,260
TY$	430,710	446,463	460,972	475,481	490,819	506,157	2,810,604

A.2 FISCAL YEAR SPREAD (FORMAL SPECIALISTS TRAINING)

Appropriation 3500	FY01	FY02	FY03	FY04	FY05	FY06	TOTAL
BY$	345,396	345,396	345,396	345,396	345,396	345,396	2,072,376
TY$	358,867	371,992	384,080	396,169	408,949	421,729	2,341,785

B. COST ELEMENT CONTENTS

Training requirements are assumed to differ between COMBAT EDGE (CE) and Libelle. With CE there is an empha
on the pressure breathing aspect that would not be present with Libelle. Turnover, then, implies there will be a differ
implication for the two systems.
This cost element addresses man-power requirements necessary to train specialists new to COMBAT EDGE enser

C. SUMMARY OF ESTIMATING AND FISCAL YEAR SPREAD PROCEDURES

The team understands the COMBAT EDGE systems at each operational unit are supported by two (2) personnel
(E-3's to E-5's) within each squadron. As training experience indicates approximately two support specialists weekly
are being replaced, new personnel are provided formal technical training for the CE system. In addition
to the formal training, there is also On-The-Job training that occurs providing the 'hands-on' experience.

D. DETAILED BASIS OF THE ESTIMATE

Training includes sizing, fitting and adjustments required for the aircrew members along with testing procedures.
It also includes the procedures for maintenance as well as what can be repaired and how each repairable item
is to be repaired. It is assumed the specialists are a composite of E-3's, E-4's and E-5's, while the instructor is
assumed an E-7.
At this time, the information on hand indicates there are 98 squadrons fielding F-15 and -16 aircraft (59 active duty;
For this estimate, it's assumed some specialists from the ANG and Reserves are replaced annually due to retireme
an assumption the specialists in the Active Duty squadrons either PCS to a non-C.E. unit or leave the service at the
enlistment. The result for these assumptions is a turn-over in personnel at the rate of 138 annually. The training sch
Sheppard AFB' best estimate is two per class (one class weekly and addit. class every third week) eventually supp
The formal training cost includes one instructor (E-7) teaching thirty (30) hours and the specialists being trained pe
These classes, per Sheppard AFB, TX, Life Support Training School, are conducted weekly with an average of eigh
students per class. In addition, every third week an additional eight (8) students are taught during an alternate class
The calculation is: instructor's hrly. rate X 30 hrs./wk. X (52+17) classes/yr. plus specialists hrly. rate X no. students
(8X52)+(8X17)=552 students
The on-the-job training assumes the specialists are mentored by a peer. The users indicate 30 days are directed to
This model assumes 172 hours per month per trainee including mentors time; total time not exclusively CE-related.
The calculation is: specialists hourly rate X no. of students X 172 hours.

Formal training time: (annually)	$345,396
OJT Training time: (annually)	$414,543

4.1.2.2 INSPECTIONS AND TESTING

Recurring periodic inspections and pressure testing are conducted monthly. Inspection and pressure testing requirements for infrequently used CE garments will not exceed six (6) months. Preflight and Post flight inspections are performed before/after each use. Under normal operational conditions each COMBAT EDGE suit will receive annually twelve inspections and pressure tests.

A. FISCAL YEAR SPREAD

Appropriation 3500	FY01	FY02	FY03	FY04	FY05	FY06	TOTAL
BY$	1,859,594	1,859,594	1,859,594	1,859,594	1,859,594	1,859,594	########
TY$	1,932,118	2,002,783	2,067,869	2,132,955	2,201,760	2,270,565	########

B. COST ELEMENT CONTENTS

This element covers cost the user will incur performing periodic preventive maintenance and general upkeep on CE

C. SUMMARY OF ESTIMATING AND FISCAL YEAR SPREAD PROCEDURES

The estimated time for accomplishing periodic inspections and pressure testing is 0.5 hours. Post flight inspections are visual inspections performed after use, and can generally be performed within five (5) minutes. These inspectio tests are performed by Life Support Specialists whose averaged hourly rates are defined in section 2.1.2 and depict in the chart below. Preflight inspections are estimated by the comparison team at ten (10) minutes to accomplish.

D. DETAILED BASIS OF THE ESTIMATE

Inspections and testing costs will occur at regular intervals throughout the life cycle of each CE ensemble.
The comparison team was provided an estimated no. of sorties annually by ACC and average duration per flight.
The number of flights provided was one hundred forty (140) and flight hours at two hundred fifty-two (252).

The inspection time is estimated as follows: (30 min. for the ITB; 45 min. for mask assembly; 10 min. pants; 5 min. Calculations: The estimated inspection time X 12 (once monthly) X hrly. wage X no. of suits yields insp./test cos The pre and post calculation is similar: est. time X no. flts. annually X hrly. rate X no. suits yields flt. Insp. activity.

Type of inspection	% of 1 hour		Occurrence	Total Time/ Suit (Hrs)
Inspection and Test	150.00%		12 times per year	18.00
Pre Flight	16.67%		140 flts. annually	23.33
Post Flight	8.33%		140 flts. annually	11.67
		Total hours per year per suit		53.00

Base Year Dollars (BY$):

Trained Life Supt.Spec	Hrly.Wage	Total Time Per Suit	Total No. of Suits	Cost / year:
Avg E3-E7 Grade - ins	$17.46	18.00	2009	$631,560
Avg E3-E7 Grade - Pr	$17.46	23.33	2009	$818,689
Avg E3-E7 Grade - Po	$17.46	11.67	2009	$409,345

4.1.2.3 UNSCHEDULED MAINTENANCE

Unscheduled maintenance is defined as corrective maintenance required by item condition. For this estimate, unscheduled maintenance is relative to sewing operations, component removal/replacement and record keeping.

4.1.2.3.1 LABOR

Based on requirements outlined in the Critical Item Development Specification (CIDS) for ATAGS and the result of the ATAGS Reliability and Maintainability Assessment by Mitre, the Mean Time To Repair (MTTR) is assumed to be 0.5 hours or less. It is important to note component replacement is presently limited to the slide fastener on the waist panel, legs and pockets, the dot snap fasteners, slide fastener stops and lacing cords.
Additionally, the specialists also maintain computer records of inspections made and items replaced.

An additional labor element is included for the removal, replacement and testing of replaced oxygen regulators and anti-g valves. The labor rate used is $17.46 per hour.

A. FISCAL YEAR SPREAD

Appropriation 3500	FY01	FY02	FY03	FY04	FY05	FY06	TOTAL
BY$	39,252	39,252	39,252	39,252	39,252	39,252	235,514
TY$	40,783	42,275	43,649	45,022	46,475	47,927	266,131

B. COST ELEMENT CONTENTS

This cost element covers the cost of labor the user will incur performing unscheduled maintenance, repairs and component removal / replacement for the COMBAT EDGE ensemble.

C. SUMMARY OF ESTIMATING AND FISCAL YEAR SPREAD PROCEDURES

The estimated time to accomplish sewing and component removal / replacement maintenance operations and the estimated percentage of maintenance requirements are per the Mitre analysis.

D. DETAIL BASIS OF THE ESTIMATE

Labor hours are estimated at 0.5 hours (time to accomplish unscheduled maintenance task on one Anti-G garment)
Labor rates are based on the per hour composite salary of E3-E7 rates defined in section 2.1.2 as $17.46 / hr.
Assume data entry actions to a computer based maintenance record system will be three (3) minutes per repair.
Air Combat Command estimates each pilot will fly 252 hours per year.
For this estimate, the requirements document data that indicates MTBF for each component is used to determine the majority of anticipated failures. In addition, one can assume some abuse and accidental damage will occur. An additional ten percent is added to the this data to account for these conditions. This information, along with average pilots flight hours annually and the number of CE ensembles in use provide an estimated overall number of failures annually.
An example calculation is: 252 flt.hrs/yr X no.suits(2009) divided by MTBF (5,725hrs) equals 88+ failures for ITBs.

Item:	MTBF hrs:	Flt. Hrs:	CE suits	theoretical Failures/yr.	additional ten percent:	Failures used:
Integrated Terminal E	5,725	252	2009	88.43	8.84	97
Mask	2,348	252	2009	215.62	21.56	237
Helmet Modif. Kit	6,599	252	2009	76.72	7.67	84
CE vest	1,756	252	2009	288.31	28.83	317
Std. Anti-g pants	714	126	4018	709.06	70.91	780
			Total:	1378.13		1516

Current consumption per data acquired by equip. specialists DLA- Phil. & DLA-Colum. indicate annual consumption for the CE ensemble appears to be approximately 215 ensembles annually. Assuming the 215 ensembles are new, items repaired equal 1,516 - 215 or 1,301. This is 1301/1516 or 85.8% of the total.

An additional labor element is included for the removal, replacement and testing of replaced oxygen regulators and anti-g valves. The labor rate used is $17.46 per hour. The estimated removal, replacement and testing of an oxygen regulator is 2.0 hours maximum and that of an anti-g valve is 1.0 hour.
The calculation is: no. of regulators X no. of hours involved X hourly rate plus no. of valves X no. of hours X hourly r

Fiscal Year:	FY01	FY02	FY03	FY04	FY05	FY06	TOTAL:
Cost / Hr. $17.46							
MTTR $ D. 0.55							
Incr. annually	85.8%	85.8%	85.8%	85.8%	85.8%	85.8%	
Total Failur 1,516							
No.Repairs/Year	1,301	1,301	1,301	1,301	1,301	1,301	
Suit Cost: (Base Yea	12,496	12,496	12,496	12,496	12,496	12,496	74,978
Reg/Valve replaceme	26,756	26,756	26,756	26,756	26,756	26,756	160,536

4.1.2.3.2 LABOR (WARRANTY REPLACEMENT)
Defects in Anti-G garments currently fielded are managed through the Product Quality Deficiency Report (PQDR) process. Thus it is assumed Libelle anti-g garments would be managed in the same manner.

4.2 UNIT LEVEL CONSUMPTION
Includes the cost of support materials consumed at the unit level.

A. FISCAL YEAR SPREAD

Appropriation 3400	FY01	FY02	FY03	FY04	FY05	FY06	TOTAL
BY$	6,960,840	6,960,840	6,960,840	6,960,840	6,960,840	6,960,840	########
TY$	7,120,939	7,232,312	7,357,608	7,503,785	7,656,924	7,810,062	########

B. COST ELEMENT CONTENTS
This element addresses the annual consumption of equipment that comprise the COMBAT EDGE ensemble.

C. SUMMARY OF ESTIMATING AND FISCAL YEAR SPREAD PROCEDURES
From data inquiries received from the POC's for CE equipment items, the following is an estimated amount of matel replaced on an annual basis, Air Force wide. This model does not address repair of aircraft components.

D. DETAIL BASIS OF THE ESTIMATE
The following information has been received pertaining to item consumption. The premise here is that some items c longer be repaired and are hence replaced. The engineering estimate is based upon experience within the team.
Pilot turnover is the basis for costing complete ensembles. The quantity used for complete ensembles assumes hel bladder modif. kits acquired will be for pilots new to CE units. This value is deducted from the U.S. average usage c the past two years for the other components making up the 'ensemble'.
The 13 B/P is used by more than CE equipped units (the quantity used is factored for A-10, F-117 and T-38 platforn
The consumption data received includes the following:

Item:	Comment:	Annual Consumption:	Cost / Item	Annual Cost:
CE Vest	4 sizes	129	394	$50,826
Integ.Term.Blk.	compl.assy.	261	320	$83,520
Anti-G Pants	4 sizes	258	575	$148,350
Oxygen Mask	4 sizes	49	1040	$50,960
Helmet Mod. Kit	3 sizes	0	180	$0
Flt. Suit Coverall	3 author.; 1 repl annually	1794	108	$193,752
G' Hoses	for anti-g suit	216	83	$17,870
Regulators	F-15 version	300	10555	########
Regulators	F-16 version	444	5179	########
Anti-G Valve	F-15 version	7	1036	$6,734
Anti-G Valve	F-16 version	37	1356	$50,172
Complete Ensemble	new aircrew to CE units	215	4152	$892,680
			Total -->	########

4.2.1 POL/ENERGY CONSUMPTION Not applicable.

4.2.2 CONSUMABLE MATERIAL / REPAIR PARTS

A. FISCAL YEAR SPREAD

Appropriation 3400	FY01	FY02	FY03	FY04	FY05	FY06	TOTAL
BY$	46,878	46,878	46,878	46,878	46,878	46,878	281,270
TY$	47,956	48,707	49,550	50,535	51,566	52,597	300,912

B. COST ELEMENT CONTENTS

This element covers costs of materials repaired in the operation, maintenance and support of CE ensembles. The only parts to require replacement are the slide fasteners (waist, legs and pockets), snap fasteners and lacing cords.

C. SUMMARY OF ESTIMATING AND FISCAL YEAR SPREAD PROCEDURES

Each CE vest and 13B/P pant garment contains the following replaceable hardware.

D. DETAILED BASIS OF ESTIMATE

This estimate reflects average case component replacement.

ITEM	QTY.	COST ea.	Cost/Suit		
CSU-13B/P:					
waist zipper	1	$7	$7.00		
leg zipper	2	$15	$30.00		
comfort zipper	2	$8	$16.00		
pocket zipper	2	$5	$10.00		
snap fastener	3	$2	$6.00		
lacing cord	6	$2	$12.00	average =	$5.06
CSU-17/P:					
chest zipper	1	$7.00	$7.00		
comfort zipper	1	$7.00	$7.00		
hose	1	$36.00	$36.00		
valve	1	$172.00	$172.00		
lacing cord	2	$2.00	$4.00	average =	$37.67

The average item cost per garment in FY00 dc CSU-13B/F $5.06 CSU-17/P: $37.67

Per the comparison team, estimate one such item per repair as there will be repairs made requiring no parts and otl

The calculation is the No. of Suits X the Matl. per Suit Cost.

Fiscal Year:	FY01	FY02	FY03	FY04	FY05	FY06	TOTAL
# of Suits *	1,097	1,097	1,097	1,097	1,097	1,097	
Matl. / Suit	$42.73	$42.73	$42.73	$42.73	$42.73	$42.73	
Total cost / Year:	$46,878	$46,878	$46,878	$46,878	$46,878	$46,878	$281,270

* No. of suits based on percent of suits repaired during unscheduled maintenance (ref. 2.1.2.3.1 - Labor)

4.3 DEPOT LEVEL REPAIRABLES Not applicable.

4.4 TRAINING MUNITIONS / EXPENDABLE STORES Not applicable.

4.5 INTERMEDIATE MAINTENANCE (EXTERNAL TO UNIT) Not applicable.

4.6 DEPOT MAINTENANCE Not applicable.

4.7 CONTRACTOR SUPPORT Not applicable.

4.8 SUSTAINING SUPPORT

4.8.1 SUPPORT EQUIPMENT REPLACEMENT
Anti-G suit ensembles are supported using test equipment and attaching cords, tubes, etc.

4.8.2 MODIFICATION KIT PROCUREMENT/INSTALLATION (AFTER PRODUCTION/DEPLOYMENT)
Not applicable.

4.8.3 OTHER RECURRING INVESTMENT Not applicable.

4.8.4 SUSTAINMENT SUPPORT

4.8.4.1 SURVEILLANCE TESTING

It is assumed by the comparison team surveillance testing will not be conducted.

4.8.4.2 LOGISTICS SUPPORT
Logistics support from the sustaining activity, HSW/YACL, is assumed moderate. This support of CE is estimated by the comparison team to require approximately one hundred twenty-five (125) hours annually of a GS-11 salary grade - level five (5) to provide adequate logistical support needed for this system. The FY00 composite hourly salary rate for a GS-11, level 5, is $48.36. Rate source: AFI 65-503, tab

Appropriation 3400 Logistics Support (BY):

Fiscal Year:	FY01	FY02	FY03	FY04	FY05	FY06	TOTAL
# of Hours	125	125	125	125	125	125	
Logis. Rate	$48.36	$48.36	$48.36	$48.36	$48.36	$48.36	
Total cost / Year: (BY	$6,045	$6,045	$6,045	$6,045	$6,045	$6,045	$36,270
Total cost / Year: (TY	$6,184	$6,281	$6,390	$6,517	$6,650	$6,782	$38,803

4.8.4.2.1 INVENTORY MANAGEMENT
This element is based on initial item issuance to aircrew member requiring ensemble - a one-time activity. Assigned as a form "538 record", there will be no ongoing inventory management activity per se. There is assumed an initial cost of approximately 12 minutes of an E-6 time ($22.86/hr.) to complete the 538 form as the ensemble is first issue
A total of: 215 forms are estimated to be completed and filed annually.
In addition to CE personal gear, there is also the replacement of CRU-93/P and CRU-98/P oxygen regulators. The usage rate is averaging 62 units monthly or 744 annually. This activity is recorded on aircraft maintenance records. The calculation for these transactions are the hourly rate X overall recording time / activity X quantities involved.

Appro.3500 Inventory	FY01	FY02	FY03	FY04	FY05	FY06	TOTAL
Total (BY)	$4,517	$4,517	$4,517	$4,517	$4,517	$4,517	$27,101
Total (TY)	$4,693	$4,865	$5,023	$5,181	$5,348	$5,515	$30,625

4.8.4.2.2 TECHNICAL MANAGEMENT
Anti-G suit ensembles are a daily use item requiring periodic inspections, testing and repairs. Therefore, technical data exists to support the system. Instructions reflected in the technical data are sufficient to maintain the system. CE technical order maintenance is estimated by a SPO equipment specialist to require seventy-five (75) hours by a grade level GS-11 annually. This activity will maintain T.O.'s current for change that may occur with suit / assoc. equipment design modifications as well as changes with procedures and policies. The FY00 composite hourly salary rate for a GS-11, level 5, is $48.36.

Appro.3400 Tech.Order Maint.(BY):

Fiscal Year:	FY01	FY02	FY03	FY04	FY05	FY06	TOTAL
# of Hours	75	75	75	75	75	75	
T.O.mtn.rate	$48.36	$48.36	$48.36	$48.36	$48.36	$48.36	
Total cost / Year: (BY	$3,627	$3,627	$3,627	$3,627	$3,627	$3,627	$21,762
Total cost / Year: (TY	$3,710	$3,768	$3,834	$3,910	$3,990	$4,069	$23,282

4.8.4.3 SOFTWARE MAINTENANCE SUPPORT Not applicable.

4.8.4.4 SIMULATOR OPERATIONS Not applicable.

4.9 INDIRECT SUPPORT Not applicable.

5.0 Annual comparison: current COMBAT EDGE (CE) system versus proposed "Libelle" system:

(including oxygen regulators and anti-g valves)

SUMMARY:	C E (BY)	Libelle (BY)	
Description:			
2.1.2.1 INITIAL INSTALLATION:			
A.1 AIRCREW LIFE SUPT / SURVIVAL EQ. SPLSTS OJT	$414,543	$192,811	
A.2 FORMAL SPECIALISTS TRAINING	$345,396	$92,106	
2.1.2.2 INSPECTIONS AND TESTING:	$1,859,594	$1,527,440	
2.1.2.3 UNSCHEDULED MAINTENANCE:			
2.1.2.3.1 LABOR	$39,252	$37,476	
2.2 UNIT LEVEL CONSUMPTION:	$6,960,840	$2,778,500	
2.2.2 CONSUMABLE MATERIAL / REPAIR PARTS	$46,878	$18,811	
2.8.4 SUSTAINMENT SUPPORT:			
2.8.4.2 LOGISTICS SUPPORT:	$6,045	$3,627	
2.8.4.2.1 INVENTORY MANAGEMENT	$4,517	$4,517	
2.8.4.2.2 TECHNICAL MANAGEMENT	$3,627	$1,934	Variance:
Summary:	**$9,680,693**	**$4,657,222**	##########

(excluding oxygen regulators and anti-g valves - not Life Support funded)

SUMMARY:	C E (BY)	Libelle (BY)	
Description:			
2.1.2.1 INITIAL INSTALLATION:			
A.1 AIRCREW LIFE SUPT / SURVIVAL EQ. SPLSTS OJT	$414,543	$192,811	
A.2 FORMAL SPECIALISTS TRAINING	$345,396	$92,106	
2.1.2.2 INSPECTIONS AND TESTING:	$1,859,594	$1,527,440	
2.1.2.3 UNSCHEDULED MAINTENANCE:			
2.1.2.3.1 LABOR	$12,496	$10,720	
2.2 UNIT LEVEL CONSUMPTION:	$1,437,958	$1,716,812	
2.2.2 CONSUMABLE MATERIAL / REPAIR PARTS	$46,878	$18,811	
2.8.4 SUSTAINMENT SUPPORT:			
2.8.4.2 LOGISTICS SUPPORT:	$6,045	$3,627	
2.8.4.2.1 INVENTORY MANAGEMENT	$4,517	$4,517	
2.8.4.2.2 TECHNICAL MANAGEMENT	$3,627	$1,934	Variance:
Summary:	**$4,131,055**	**$3,568,778**	**($562,277)**

Note: "BY" is FY00.


AIR OPERATIONAL TEST & EVALUATION CENTER